POWER PLANT ENGINEERING

Established Over 33 Years

VOL. XXXIII CHICAGO, APRIL 1, 1929 No. 7

EDITORIAL STAFF — ARTHUR L. RICE, Editor; R. E. TURNER, Managing Editor; A. W. KRAMER, Associate Editor; CHESTER R. EARLE, Associate Editor; RICHARD H. MORRIS, Associate Editor; EDWARD J. KUNZE, Associate Editor

Contents of this Issue

Page

New Power Plant of National Biscuit Co. Meets Exacting Power and Steam Demands of Modern Bakery 396

Flywheels for Boiler Output 400

Long Beach No. 3 Attains Fuel Economy of 12,880 B.t.u. per Kw-Hr. By W. D. Campbell 404

Many Factors Cause Turbine Blade Failures. By W. E. Warner 408

Lubricant Reclamation Reduces Power Station Upkeep—II 409

Errors in Electrical Instruments. By W. E. Warner 411

Lightning 412

Electricity—What It Is and How It Acts. By A. W. Kramer 417

Installation of Diesels Overcomes Water Supply Troubles 421

Adapting Pulverized Fuel to Marine Boilers 424

Edison Was Disguised. By Hubert E. Collins 426

Natural Gas for El Paso Power. By M. W. Baker 427

Unit Heater Tests Show High Heat Transfer 428

High-Pressure Boiler for Safety Valve Testing 431

Steam Fuel from a Resin Mine 432

Loss of Head in Trash and Ice Racks. By Morrough P. O'Brien 433

Letters Direct from the Plant: Longitudinal Attachment of Water-Leg Introduces Severe Stresses. How You Do Things Is Important. Pulverized Coal—How Fine? Simple Eye Making Device. Engine Speed Change Limitations 437

Questions and Answers: Flat Plate Orifice for Flow Measurement. Tests for CO_2 Leakage in Refrigerating Systems. Overall Efficiency Measurement. Exhaust Steam Injector Action 440

Editorial Comment: Names for Things. Progress in Lightning Research. Splitting Hairs in the Hydro-electric Plant. Power Plant Engineer's Debt to the Chemist 442

Multiple-Feed Lubricators for Oil and Grease 444

Link-Belt Gasoline Locomotive Cranes 445

Ideal Commutator Mica Undercutter 445

Illinois Utilities Meet at Springfield 446

Russian Government Engages American Engineers 446

News Notes 447

Books and Catalogs 449

Published on the 1st and 15th of each Month by the

Technical Publishing Co., 53 West Jackson Blvd., Chicago

New York Office, 171 Madison Avenue

Subscription price $2.00 a year in the United States and possessions. Canada $2.75 a year. Other countries $3.50 a year. Single copies 15 cents.

Copyright 1929, by Technical Publishing Co.

Entered as second class matter May 1, 1908, at the Post Office at Chicago, Illinois, under the act of March 3, 1879.

Member, Associated Business Papers, Audit Bureau of Circulations.

Circulation of this issue 23,900

Lampyris Noctiluca

HERE, CHILDREN, is the fuzzy little Lampyris Noctiluca. This strange creature sleeps all day and comes out only at night when all good little kiddies are asleep and when only power plant operators and night club habitués are awake. Lampyris Noctiluca, however, never goes to night clubs—indeed no, she is a good little girl; furthermore, she doesn't need to go to night clubs to get lit up. And she never associates with power plant operators; she hates 'em.

Well, then, how does she get lit up that way? Sshh—that's a secret, but we'll tell you. She was born that way. Would you believe it?

But it's true. Some day next summer when you have been particularly good, ask your daddy to let you stay up till it's way late and then go out into the garden and there you will see a lot of little Lampyris Noctiluca. Daddy will tell you they are glow worms or lightning bugs, but that's only because he doesn't know what he's talking about—he's bluffing as usual. Just tell him, boloney, you know better.

This particular Lampyris was found by Mr. Peek of the General Electric Co., crawling around the Pittsfield laboratory. He came back after work one night to look for a small lightning bolt he had lost and when he opened the door, there was this funny little glow worm climbing up a string of 27 insulators. Always alive to any situation, Mr. Peek, quick as the lightning he makes, grabbed a voltmeter and a camera and while he measured the potential with one hand, he took a picture with the other. And here she is. We had to turn the picture on its side. As Mr. Peek explains on page 412, this specimen measured *5 million volts!*

So, children, don't ever touch a Lampyris Noctiluca, unless by chance it happens to be a male. The female of the species is just what Kipling said it was.

New Power Plant of

NATIONAL BISCUIT CO. *meets exacting* Power and Steam Demands *of* Modern Bakery

THREE OF SEVERAL National Biscuit Co. plants in Chicago, the Kennedy, Uneeda and Nabisco Bakeries are located in a single block bounded by North Morgan, West Randolph, North Sangamon Streets and Washington Boulevard. They are supplied with power, refrigeration, process and heating steam from a single well-designed and efficiently operated power plant shown in the cross section, Fig. 1.

Steam at 150 lb. pressure 120 deg. F. superheat is generated in three 288-hp. Babcock & Wilcox boilers, fired by Type E stokers. Electric power is generated at 450 v. by three 310 kv-a. Crocker-Wheeler three-phase, 60 cycle alternators, direct connected to Skinner 200 r.p.m., 23 by 24-in. Unaflow engines. The engines are all equipped with Ludeman safety stops which protect the engines against overspeed and enable the engine to be stopped manually from the switchboard and several other points in the engine room.

Coal, received by truck, is dropped by gravity into the coal vault located underneath the sidewalk on North Morgan Street. From the coal vault, it is brought in as needed, weighed on a Buffalo scale and shoveled into the stoker hoppers by the firemen. At present Indiana bituminous screenings running about 11,500 B.t.u. per lb. is used.

Boilers are 288 hp, 200 lb., longitudinal drum straight tube type, 12 tubes high and 12 wide, with two 36-in. drums and 144 4-in. tubes 20 ft. 7 in. long. Each boiler has a Foster superheater, Yarway tandem blowoff valves, S-C feedwater regulator, Reliance water column, six element Marion soot blowers, Brown CO_2 meters, Bailey three pointer draft gauge, Enco balanced draft system and three Consolidated safety valves, two on the drums set at 175 lb. and one on the superheater set at 178 lb.

Forced draft for the stokers is supplied by a Sirocco size 110 fan located on the gallery as shown in Fig. 1. This fan is driven by two 5 by 5-in. American Blower Co. steam engines, controlled by the steam pressure through a Mason regulator.

Feedwater is heated by a Cochrane open feedwater heater located on the gallery next to the fan and directly above the two Worthington outside end packed, pot valve, 10 by 6 by 10-in. horizontal duplex boiler feed pumps. Both pumps are controlled by S-C pump governors and are protected from overspeed by Mason regulators. City water is used as makeup in the boiler feed system and treated with compound on the basis of weekly tests made by W. B. Coleman Co. Compound is fed to the boilers by a 3 by 2 by 3-in. Worthington steam pump. Hot water for the entire plant is supplied from the Berryman heater shown behind the boiler in Fig. 1.

Smoke Indicator Always Visible to Fireman

A unique feature of the boiler room is the smoke indicator. This consists of a small blower driven by a ¾-hp. motor. The fan is connected by piping to the boiler uptake and discharges through a nozzle into a hood which contains an electric bulb. If the boiler is smoking some of the smoke will be drawn through the fan and when discharged against the light background is plainly visible to the fireman from any position on the firing floor.

From the steam header above the boilers, four steam lines supply the three engines and steam driven exciter.

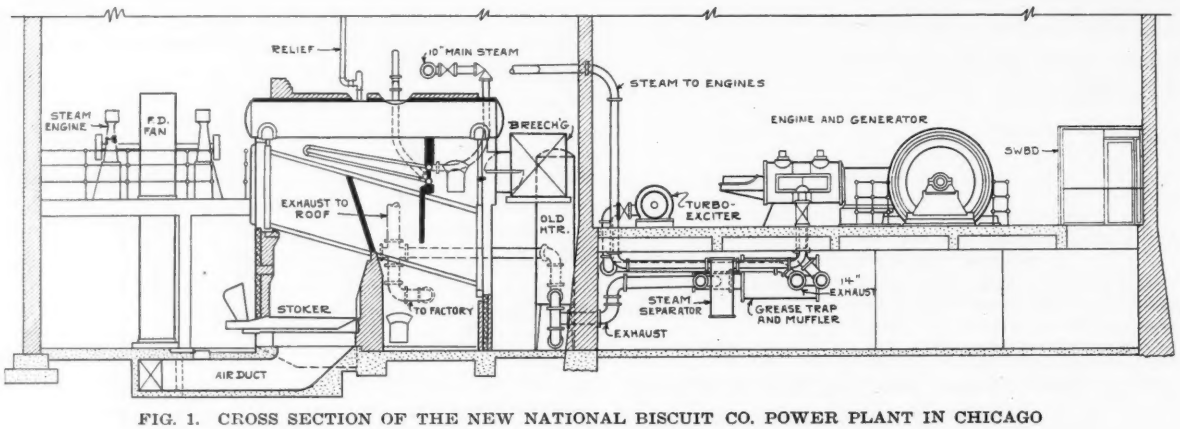


FIG. 1. CROSS SECTION OF THE NEW NATIONAL BISCUIT CO. POWER PLANT IN CHICAGO

All steam and exhaust piping in the engine room is below the floor and each machine has an individual separator, the separators being drained by Armstrong traps which discharge directly to the feedwater heater. Exhaust steam at 2 to 3 lb., after passing through the grease extractor, is used for heating the buildings, general service and boiler feedwater.

tank service water pressure and boiler feedwater flow meter. With the exception of the Brown flow meter, all of these instruments are Foxboro.

Excitation for the main generators is furnished normally by a Crocker-Wheeler synchronous exciter set; a 150-kv-a., 900-r.p.m. synchronous motor driving one 45-kw. 125-v. and one 10-kw., 125-v. direct current gen-

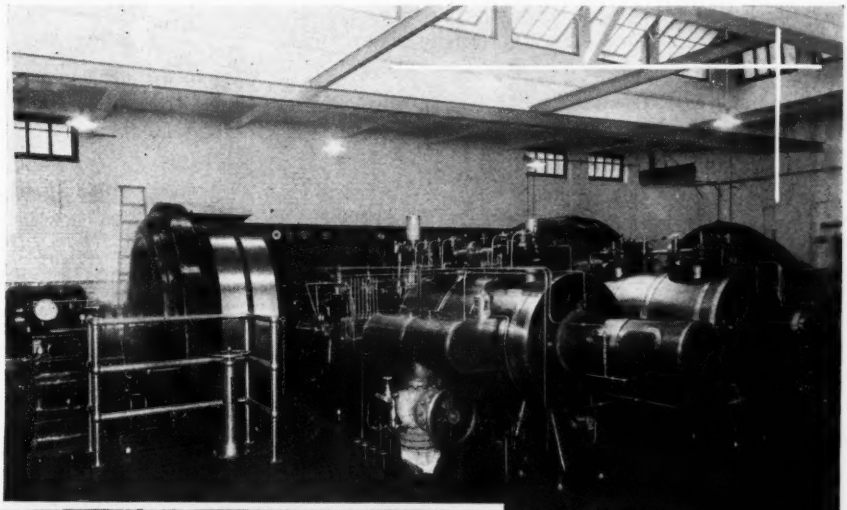


FIG. 2. ELECTRIC POWER IS SUPPLIED BY THREE UNAFLOW ENGINES

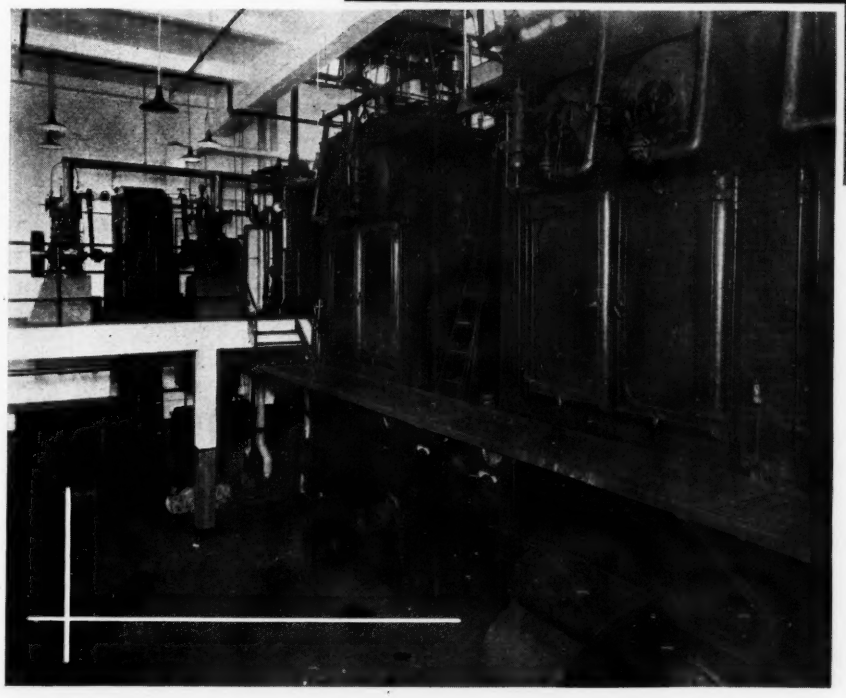


FIG. 3. THE FORCED DRAFT FAN LOCATED ON THE GALLERY FLOOR, IS DRIVEN BY TWO STEAM ENGINES

If the exhaust steam is not sufficient to supply the heating demands, live steam is admitted to the system through S-C reducing valves. If there is an excess of exhaust steam, it is vented to atmosphere through a Cochrane atmosphere relief valve located near the feedwater heater. Process and factory steam at 75 lb. is supplied through Boylston reducing valves.

All steam gages and instruments are mounted on a single board in the engine room. Those instruments show the superheat on each boiler, the steam and back pressure on the engines, the factory steam pressure, vacuum pump suction, sprinkler system pressure, house

erator. In case of emergencies or for starting a 40-kw., 125-v. Crocker-Wheeler exciter driven by a De Laval 1800-r.p.m. steam turbine is provided. A 250-kv-a. Crocker-Wheeler synchronous condenser as shown in the upper right-hand corner of Fig. 4 and the left-hand side of Fig. 2 is used for power factor correction.

Electric power distribution is handled by a 15-panel Westinghouse switchboard with Westinghouse instruments, switches, synchronizing panel and Type AE2 voltage regulator. The power load is recorded by an Esterline-Angus strip recording meter.

Refrigeration demands are taken care of by an 80-t.

10½ by 17-in. Frick duplex ammonia compressor driven by an Electric Machinery Mfg. Co., 175-hp., 440-v., 100-per cent p.f., 120-r.p.m. synchronous motor. The exciter is a 75-kw., 125-v., 1750 r.p.m. compound wound unit driven by an 11-hp., 440-v. motor. The double-pipe condenser is supplied with cooling water by two Goulds 150-g.p.m., 45-ft. head centrifugal pumps driven by 3-hp., 440-v. Crocker-Wheeler motors.

Cooling Water for Ammonia Condensers Comes from City Mains

Cooling water, taken from the city mains, goes to a surge tank located near to and slightly above the pumps. Water is maintained at a predetermined level by Klipfel regulating valves. The pumps take their suction from the surge tank, pump the water through the condenser and then up to the general supply tank on the roof. The water used is metered by a Worthington Model D disc meter.

As shown by Fig. 4, three brine tanks are installed. The Goulds brine pumps, used for circulation, are two 500-g.p.m., 125-ft. head, 1750-r.p.m. pumps driven by 35-hp., 440-v. Howell motors and one smaller 106-ft. head pump driven by a Crocker-Wheeler, 5-hp., 440-v. motor. A Worthington disc meter is installed in each line and Foxboro gages and Tycos thermometers are used. All brine lines are covered with 4 in. of cork.

Another of the interesting features of the plant is the well-laid out lubricating and cylinder oil systems. Two 168-gal. tanks are located above the boilers. One of these is for lubricating oil and the other is for cylinder oil. From these tanks, the oils feed by gravity to the bearings direct or to individual mechanical lubricators on the various machines.

From the bearing, the reclaimed lubricating oil flows by gravity to the Bowser filter in the basement. After filtering, the oil is pumped back to the gravity tank, through an oil cooler, by two float controlled pumps driven by 1½-hp., 440-v. 1150-r.p.m. motors. Crane relief valves on the pumps are set for 35 lb. Before filtering the oil is heated to about 120 deg. Cylinder oil is pumped from a storage tank in the basement by a similar pump with hand control.

In addition to the two oil tanks and filters mentioned, five additional tanks are installed. These are for motor oil, machine oil, ammonia compressor oil, kerosene and boiler compound. The ammonia compressor has a small Bowser filter and an individual lubricating pump driven from the motor shaft. All tanks can be filled from a loading platform on the floor above.

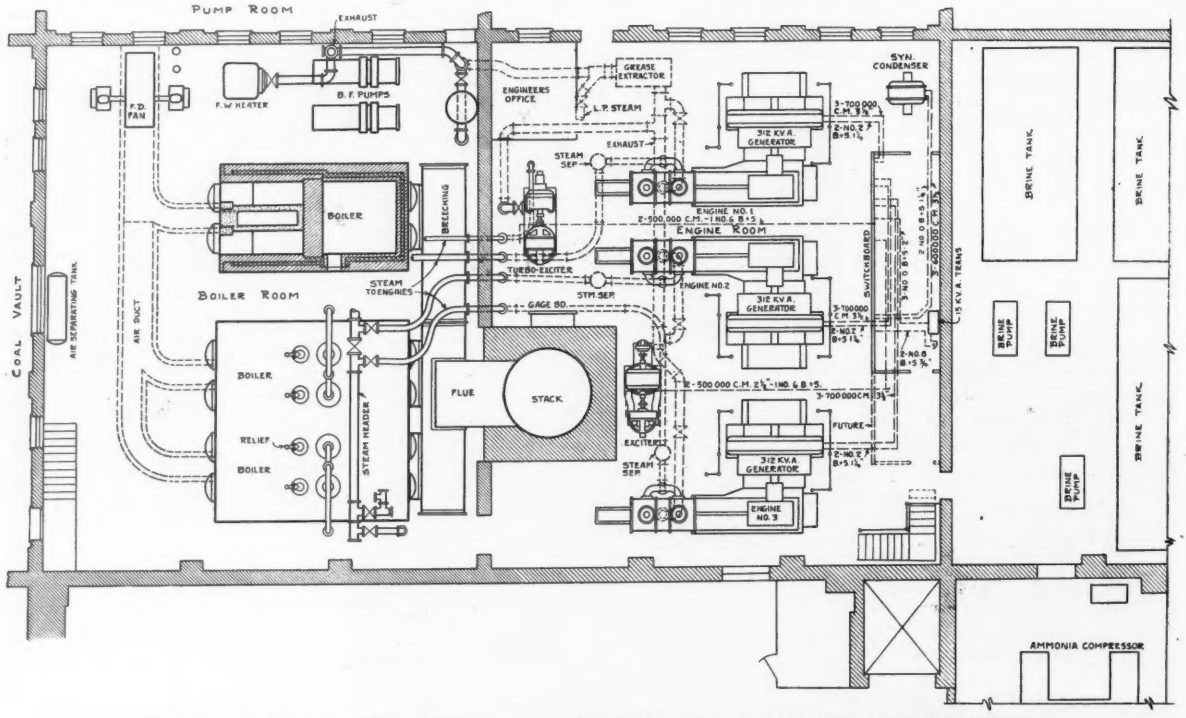


FIG. 4. PLAN OF THE POWER PLANT SHOWING THE STEAM AND EXHAUST PIPING

Color System Used for Pipes

Drains from the plant are piped to a dirty drip tank in the basement and discharged by an S-C drainage control system. A small Westinghouse compressor and receiver are installed for general service and to maintain pressure on the fire system. Other miscellaneous equipment includes a storage battery and a Tungar battery charger for the Brown CO_2 meter and batteries with a Rectigon charger for the fire system alarms.

A comprehensive color scheme has been incorporated for the piping systems; the following are some of the colors being used: live steam, white; exhaust steam, brown; city water, orange, and hot water, green.

This plant, which is a model of design for industrial plants where reciprocating engines can be used to advantage, was designed by D. M. McKelvey, consulting engineer for the National Biscuit Co., and is operated under the direction of H. E. Goan, manager of power plants for the National Biscuit Co. plants in the Chicago district.

FIG. 5. THE 80-T. AMMONIA COMPRESSOR IS DRIVEN BY A 120-R.P.M. SYNCHRONOUS MOTOR RATED AT 175 HP.

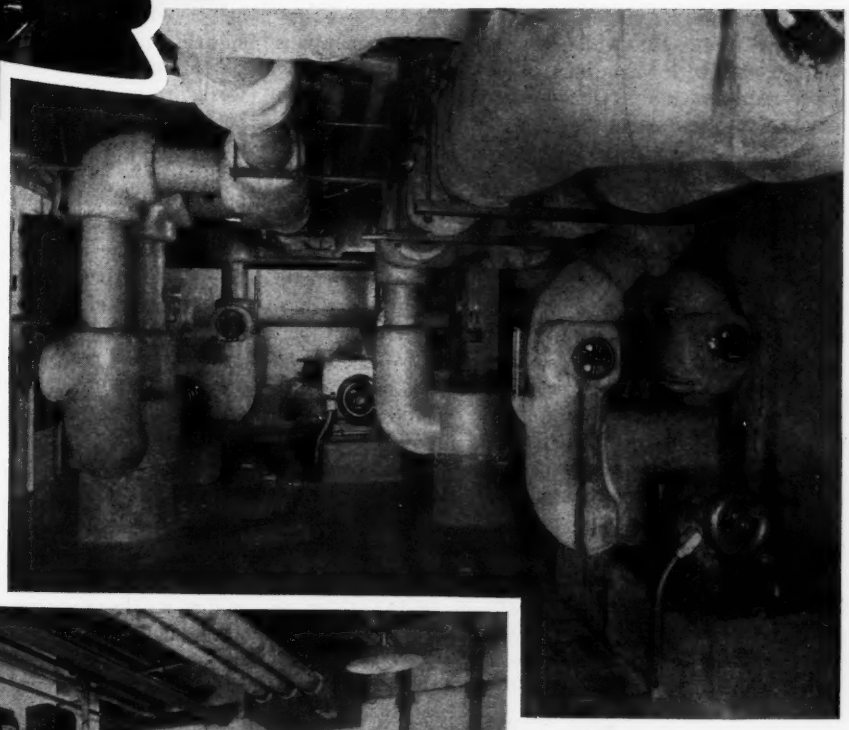


FIG. 6. BRINE PUMPS AND PIPING ARE WELL INSULATED WITH HEAVY CORK

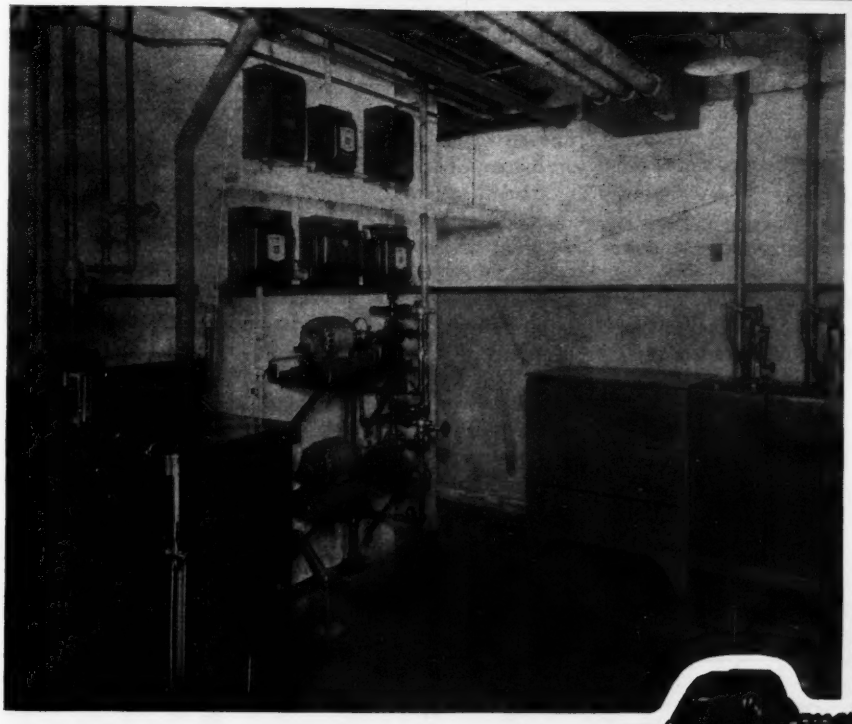


FIG. 7. THE SYSTEM FOR DISTRIBUTING AND RECLAIMING THE OIL IS ONE OF THE FEATURES OF THE PLANT

FIG. 8. THE MOTOR DRIVEN EXCITER. THE PIPES FROM THE GRAVITY OIL TANK CAN BE SEEN PLAINLY

Flywheels for Boiler Output

STEADY PRESSURE, STEADY LOAD AND LESS TOTAL STEAM USED ARE RESULTS OF THE USE OF STEAM ACCUMULATORS

PROCESS STEAM for industries is likely to be required in amounts which vary widely and sometimes rapidly, also with variations in no way related to the power requirements of the plant. As between the two demands, process steam and power, a balance wheel or accumulator is needed to store and return energy so that both demands may be met as they arise. Of the two, the steam demand is the more likely to fluctuate rapidly and widely, which, unless some form of accumulator is provided, requires that boiler capacity in excess of average requirements be provided, or that the steam supply be curtailed during peaks of demand, sometimes to the point of reducing output of the plant product.

In one plant, it was found that the peak steam supply was being limited to 57,000 lb. an hour, whereas, for best output, 85,000 lb. an hour should have been furnished. As the main peak lasted for only one hour in a day, with a secondary peak of 70,000 lb. an hour for 15 min., it was not thought good economy to install the extra boiler capacity needed and operate it for these short periods.

By using an accumulator, it was possible, without increasing installed boiler capacity, to make full use of the plant capacity for product. This is not an isolated case, as increases of 10 to 30 per cent in plant product have frequently been achieved.

HEAT IS EASILY STORED

Storage of energy on the power end seems to be possible only by means of the storage battery for any large quantities, and is expensive. Storage of heat, on the other hand, by passing steam into water and re-evaporating at a lower pressure, is simple and inexpensive. Also it is easy to take care of any unusual excess peak demands for steam above what the accumulator can supply, while such unusual peaks for power are more difficult to handle. This is because the boiler has a wider range of excess capacity than does the engine, turbine or electric generator.

In cases where the steam requirements for process work are greater than those for power, live steam can be bypassed through reducing valves to the process supply but, even in such cases, if the process demand fluctuates widely, it may result in excess boiler capacity, or uneconomical operation of the boiler plant. Also wide variation in steam demands is likely to result in variable boiler pressure, which will affect the speed of the electric generators and power delivered, also the effectiveness of the process work, if the pressure and temperature at which process steam is supplied vary.

For these reasons, it may often prove economical to use an accumulator to steady the load on the boiler even though boiler plant capacity is equal to all steam demands.

PRESSURES VARY WITH STEAM DEMAND

Fluctuation of steam demand in a cotton mill is shown in Fig. 1, with a line to indicate what a steam accumulator would accomplish in steadying the demand on the boilers. Figure 2 gives like data for an oil refinery. In a paper mill, the digesters call for such large amounts of steam at irregular intervals that boiler pressure is affected as shown in Fig. 3. Not only would this vary the temperature of steam to the machines but speed of the generator turbine would vary, resulting in uneven thickness and possibly in breakage of the paper on machines.

ACCUMULATOR CAPACITY NEEDED

Heat which can be stored in water and returned in steam depends, of course, on the amount of water used and on the range of pressure variation in the accumulator. Figure 4 shows the steam capacity per cubic foot of water for various pressure ranges. For instance, with live steam supplied at 200 lb. and low-pressure steam delivered at 50 lb. gage pressures, a cubic foot of water will deliver 5.5 lb. of steam. If, then, as in Fig. 2, from 6:45 o'clock to 9:15 it will be required to furnish 17,500 lb. of steam from the accumulator, the water needed will be 17,500 ÷ 5.5 = 3182 cu. ft. If

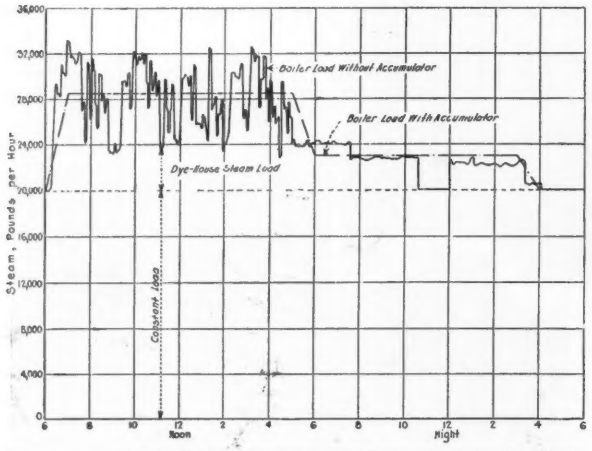


FIG. 1. DAILY STEAM CONSUMPTION CURVE FOR COTTON MILL AND DYE HOUSE

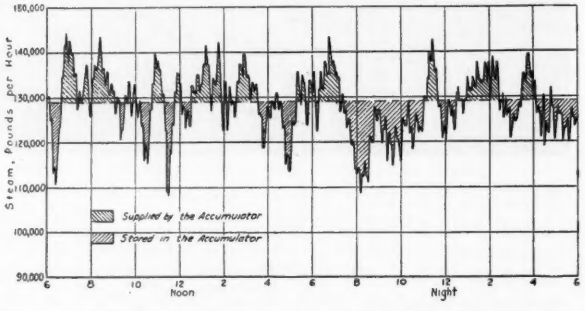


FIG. 2. EFFECT OF STEAM ACCUMULATOR IN LEVELING STEAM DEMANDS OF AN OIL REFINERY

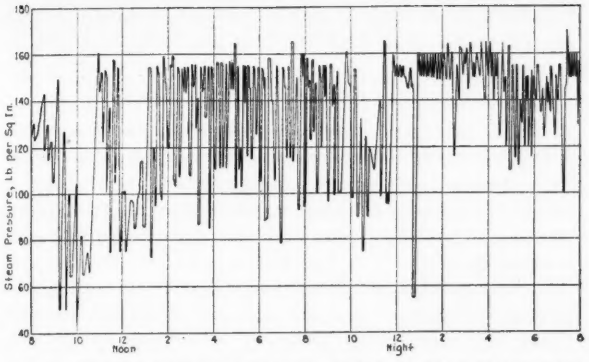


FIG. 3. PRESSURES WERE SERIOUSLY AFFECTED IN THIS PAPER MILL BY VARYING STEAM DEMAND

the accumulator, as is usual, is kept 0.9 full of water, its volume should be 3182 ÷ 0.9 = 3535 cu. ft.

Valves for Control of Steam Flow and Pressure

To control action of the accumulator, valves must be provided to regulate the flow of steam. The different conditions to be met are: 1. Process demand less than average, when live steam and perhaps exhaust should be stored in the accumulator. This will call for an overflow valve to handle the live steam and a non-return inlet valve to take the exhaust and reduced-pressure steam to the accumulator. 2. Process demand greater than average, when exhaust steam and steam from the accumulator will flow to the process supply main. Valves needed will be a non-return valve to take outflow from the accumulator and a reducing valve between the accumulator and low-pressure process mains. 3. Process demand greater than power demand and the supply from the accumulator exhausted. Exhaust steam, and live steam through a reducing valve must be supplied to the process supply main; some steam may also go to the accumulator, if process demand is less than the average boiler load. 4. Process demand less than the average and accumulator fully charged. To prevent over pressure in the accumulator, if it is built for less than boiler pressure, a valve must throttle steam supply to the accumulator.

Action of the Accumulator

Arrangement of an accumulator, pipe connections and valves is shown in Fig. 5. Connection from the boilers is through pipe N, with a stop valve to shut off

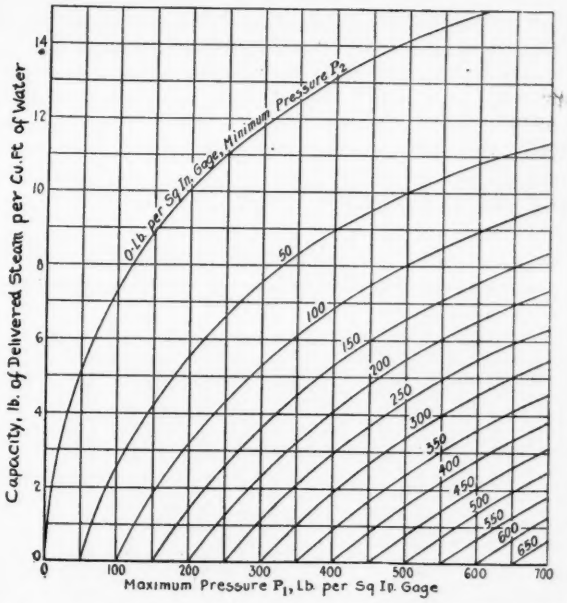


FIG. 4. STEAM STORAGE CAPACITY OF WATER BETWEEN DIFFERENT PRESSURES

or admit steam to the accumulator and process supply main. Pressure is reduced from boiler pressure to the maximum allowed in the accumulator by valve V_1 and further to process pressure by valve V_2. This insures steady pressure in the process main as accumulator pressure varies or when live steam is passed direct to the process system. In case two process pressures are used, a third reducing valve may be needed with the higher pressure process line connected between the high and intermediate reducing valves. But the one connection to the accumulator will always be just ahead of the reducing valve leading to the low-pressure process main as shown in Fig. 7.

Steam flow to and from the accumulator is through pipe O, with stop valve at the connection to the process system. Flow to the accumulator is through nonreturn valve E and a stop valve to distributor pipe F and nozzles G, which give circulation of the water and noiseless condensation of the steam. Outflow from the accumulator is through a nozzle K, so designed as to

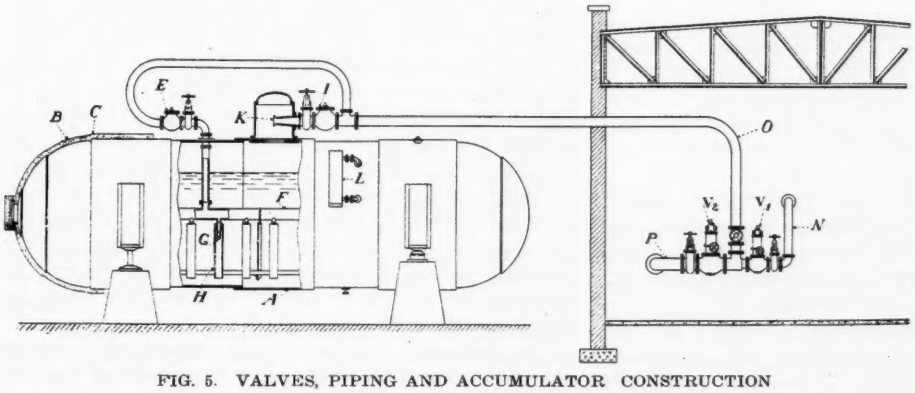


FIG. 5. VALVES, PIPING AND ACCUMULATOR CONSTRUCTION

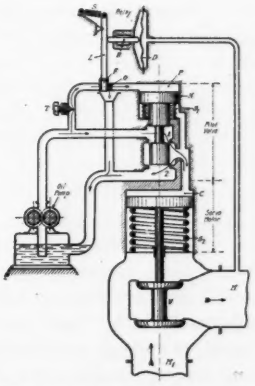


FIG. 6. PRINCIPLE OF OIL-REGULATED STEAM VALVE TO MAINTAIN STEADY BOILER PRESSURE AND OUTPUT

prevent excess flow in case of a break in the piping of the system, a stop valve and non-return valve I.

As shown, the shell is of steel plate with hemispherical ends and 3-in. insulating covering B, having special blocks over the joints, as at C, which can be easily removed for inspection of the joints. Water column L and a safety valve on the steam dome are provided, the water level being carried so that 90 per cent of the volume of the shell is filled with water. Support is by four brackets; one is rigidly fixed, two rest on rollers, one for lateral, the other for longitudinal movement; while the fourth is a pendulum support, allowing displacement in any direction.

Thus arranged, the accumulator is suited for outdoor installation, in the open, requiring only foundation sufficient to carry the weight. It requires practically no attention or upkeep expense, as the shell and piping are protected by a weatherproof covering over the insulation.

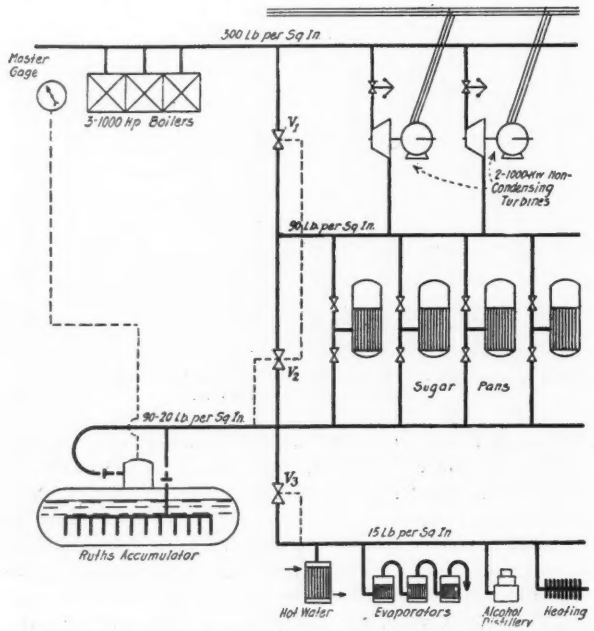


FIG. 7. THIS INSTALLATION IN A SUGAR REFINERY BALANCES LOAD AT THREE PRESSURES

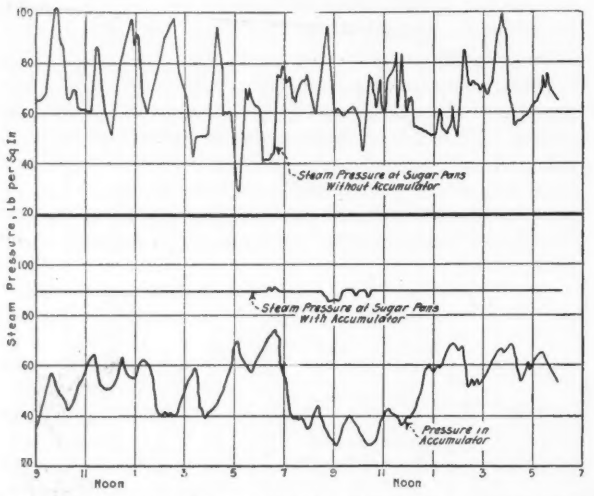

Steam Pressure, Lb per Sq In
Steam Pressure at Sugar Pans Without Accumulator
Steam Pressure at Sugar Pans With Accumulator
Pressure in Accumulator
Noon
Noon

FIG. 8. RESULTS IN STEADYING PRESSURE BY THE USE OF ACCUMULATOR IN A SUGAR REFINERY

Control Valve of Special Design

Valve V_1, since it acts as an overflow valve, a reducing valve and an overpressure valve, is of special design. The principle of action is shown in Fig. 6, the design being to maintain constant pressure in main M, leading to the accumulator. Boiler steam comes through connection M_2.

Constant flow of oil is maintained by the oil pump, part of this going through regulator T and part through chamber 1. Oil which passes T either goes to chamber P or escapes through openings O to the overflow leading to the pump suction. Pressure in P is determined by the amount of oil escaping through O and this is determined by position of the sleeve F, controlled by lever L.

If pressure in M falls, steel diaphragm D moves to the right, allowing pin R to follow it, and lever L swings to the right, moved about its knife-edge by spring S. This action partly closes O, increasing the pressure in P, which forces piston N downward against spring S_1 and increases the outlet for oil from chamber 1 into chamber C, also closing outlet into chamber 2. Pressure in C is thereby increased, forcing the servomotor piston downward against spring S_2 and increasing the opening of valve V so that more steam can flow from M_1 to M.

At the same time, increase of pressure in C acts on the under side of N, returning it to its original position,

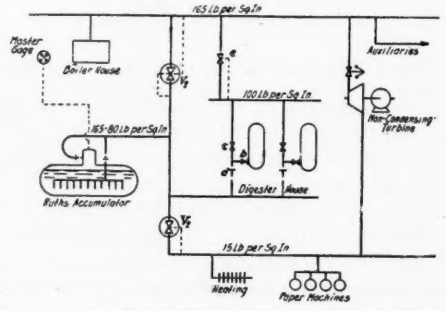


FIG. 9. TYPICAL INSTALLATION IN PULP AND PAPER MILL

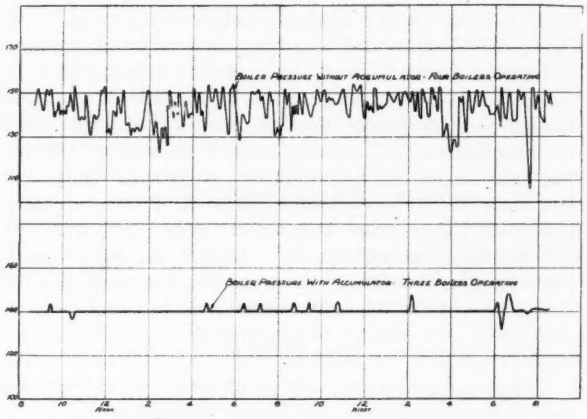

Boiler Pressure Without Accumulator - Four Boilers Operating
Boiler Pressure With Accumulator - Three Boilers Operating

FIG. 10. BOILER PRESSURE WAS STEADIED AND ONE BOILER SHUT DOWN IN A PULP AND PAPER MILL

thus closing ports 1 and 2 and bringing the servomotor piston to rest without "hunting."

Increase in the pressure in M will result in a converse action all the way through, so as to close valve V.

Actual design embodies all these features except the oil pump in a single compact construction, with a handwheel to permit operation of valve V independently of the relay and a trip lever to permit instantaneous closing in case of emergency. Adjustments are provided for setting the valve to the exact pressure to be held and for varying the time of a full stroke from 1/5 to 60 sec., also for varying the sensitiveness of action.

If the sleeve F be placed at the right of orifices O, pressure in M_1 can be maintained constant, the valve acting as an overflow. Also, by adding diaphragms to act on the same lever L, the overflow and pressure reducing functions may be combined in one valve, as

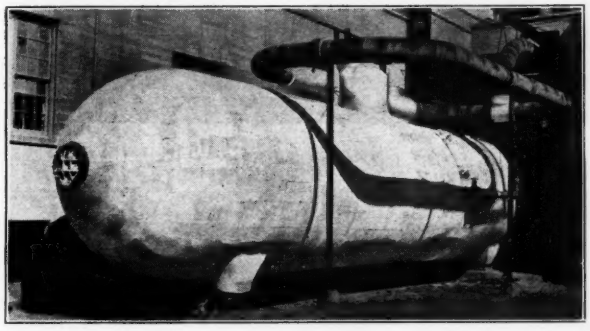


FIG. 11. THE RUTHS STEAM ACCUMULATOR AS IT APPEARS IN SERVICE

has been done satisfactorily for varied requirements of regulation.

Control of Three Pressures Possible

In practical application, the accumulator may function, where only process steam is used, to steady the demand on the boiler plant; or where power is generated and exhaust steam used for process work, floating on the system to equalize between power and process requirements; or where two process pressures are used, the accumulator may act as a balance between the two process demands, at the same time serving as a flywheel to steady boiler load by taking overflow steam throttled to the higher process pressure.

Figure 7 shows the arrangement for the last mentioned conditions in a sugar refinery. Generator turbines work between 300 lb. boiler pressure and 90 lb. back pressure, at which steam is used in the sugar pans. Outlet from the pans is at 20 lb. to heaters, evaporators and stills. The accumulator works between 90 and 20 lb., taking up excess steam from turbines or pans not needed in the 15-lb. main, also taking live steam from the boilers through reducing valve V_1 to steady the boiler load. When the 15-lb. main has heavy load, the accumulator supplies any lack of steam, if pans and turbines are working at light load, or if the accumulator becomes discharged, live steam may pass through reducers V_1, V_2 and V_3 direct to the 15-lb. main.

Results obtained are shown in Fig. 8, the upper curve showing the pressure variation at the pans without the accumulator; the middle line, the steadying of that pressure when the accumulator was in use; and the lower curve, the way that accumulator pressure varied in storing and delivering steam. An increase of 15 per cent in production resulted.

Steady Pressure Aids Generator Regulation

In a pulp and paper mill, a similar installation, shown in Fig. 9, operated with pressures of 165, 100 and 15 lb., the turbine exhausting to the 15-lb. main and the accumulator balancing loads as between the digesters and the paper machines. Here, by maintaining boiler output and pressure steady, the speed of the turbine was held constant so that difficulties with the operation of the paper machines were overcome. At the same time, three boilers were sufficient to operate the plant as against the four previously needed. With the four boilers, pressure varied as shown in Fig. 10, upper curve, while the "after" condition with three boilers operating is shown by the lower line.

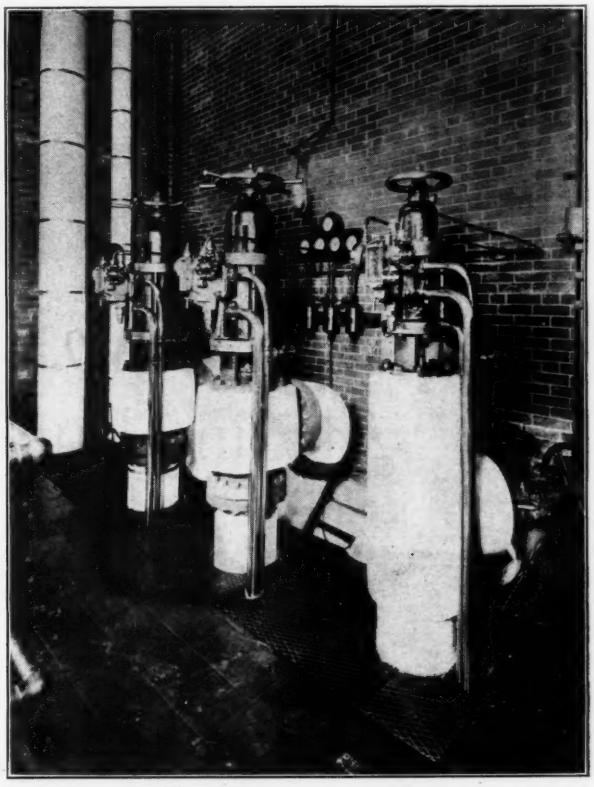
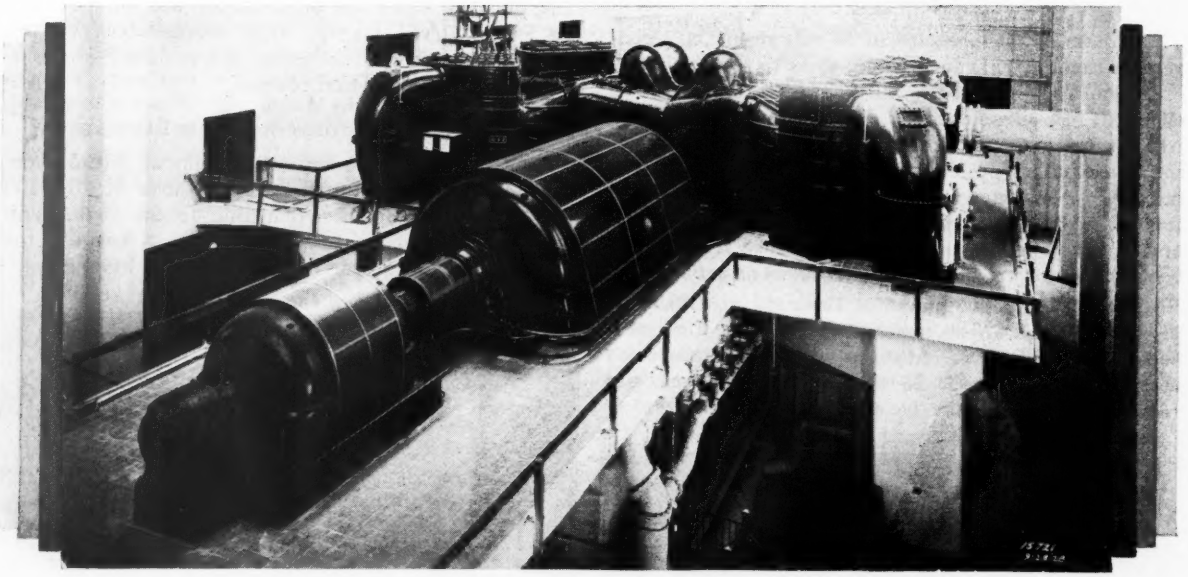


FIG. 12. INSTALLATION OF REGULATOR VALVES

A typical accumulator with its piping is as seen in Fig. 11, while the installation of automatic regulator valves is shown in Fig. 12.

About 1680, Huygens built an internal combustion engine using gunpowder. The explosion forced the heavy piston upward and the external work was done by the piston as it was forced back into the cylinder by atmospheric pressure. It was not until almost 200 yr. later that Lenoir built a successful internal combustion engine having the fuel charge act directly on the piston to do external work.



Long Beach No. 3 Attains Fuel Economy of 12,880 B.t.u. per Kw-hr.

By W. D. Campbell

OPERATING DATA for the Long Beach Steam Plant No. 3 of the Southern California Edison Co. from July 1 to December 6, 1928, a total of 132 days, indicate a production of 499.56 kw-hr. per barrel of oil plus 143 bbl. of standby oil per day. This is equivalent to an overall performance at 100 per cent load factor of 485 kw-hr. per bbl. or a heat consumption of 12,880 B.t.u. per kw-hr. Practically identical results are obtained by using the figure 500 kw-hr. per barrel of oil plus 150 bbl. per day standby.

These results are not materially different from those formerly found from plottings of daily operations up to July 30 when the figures indicated a production of 495 kw-hr. per barrel of oil plus 146 bbl. per day for standby; the standby figure was arbitrarily raised to 150 bbl. per day.

The present result was obtained by arranging the daily readings of kilowatt-hour output and oil used in a table showing nine zones. Zone I is from 1000 to 249,000 kw-hr. per day and the zones increase in steps of 250,000 kw-hr. up to Zone IX for 2,000,000 kw-hr. a day or more.

The method of arranging the data is shown in Table II. These readings were averaged by dividing the total for each zone by the number of days run for each zone, thus making it possible to plot the economy curve shown in Fig. 3. The slope of this curve, indicating the average standby and kilowatt-hours per barrel of oil, was determined mathematically by adding the amounts of the first six zones and using this sum as one point on the curve and then adding the amounts of the last three zones, using this sum for a second point on the curve.

Comparison of Actual and Estimated Fuel Consumption

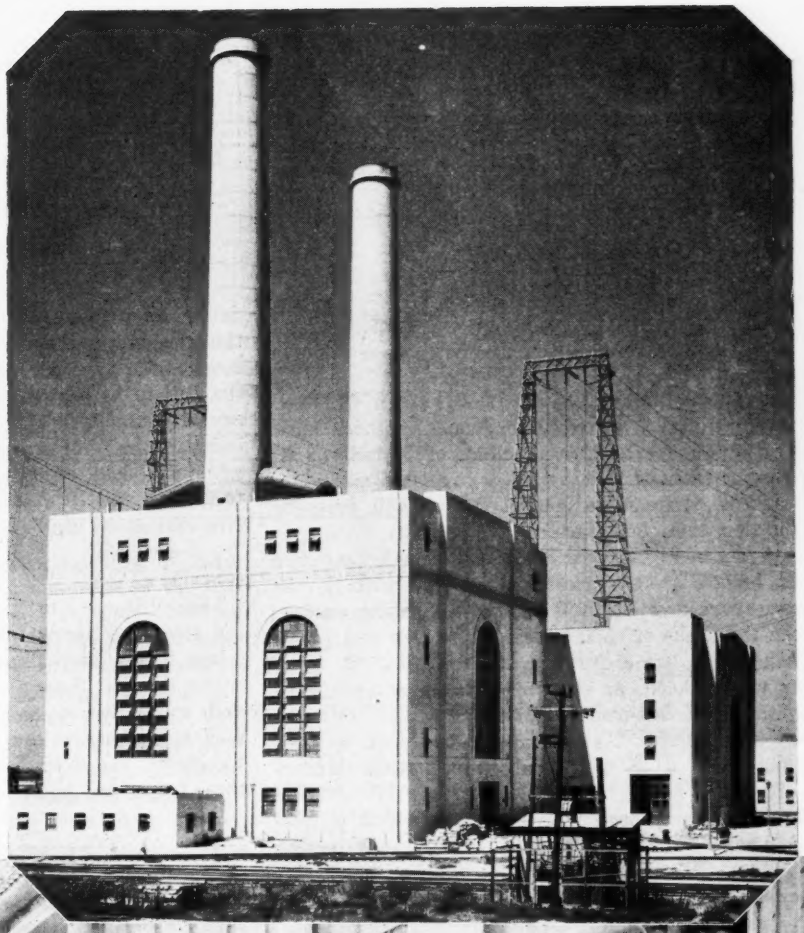
Table I shows a summary of the fuel economy of the plant for five months, July to November, 1928, inclusive, presenting a comparison of the amount of fuel actually used with the amount estimated for the same period in accordance with the fuel economy equation of the plant:

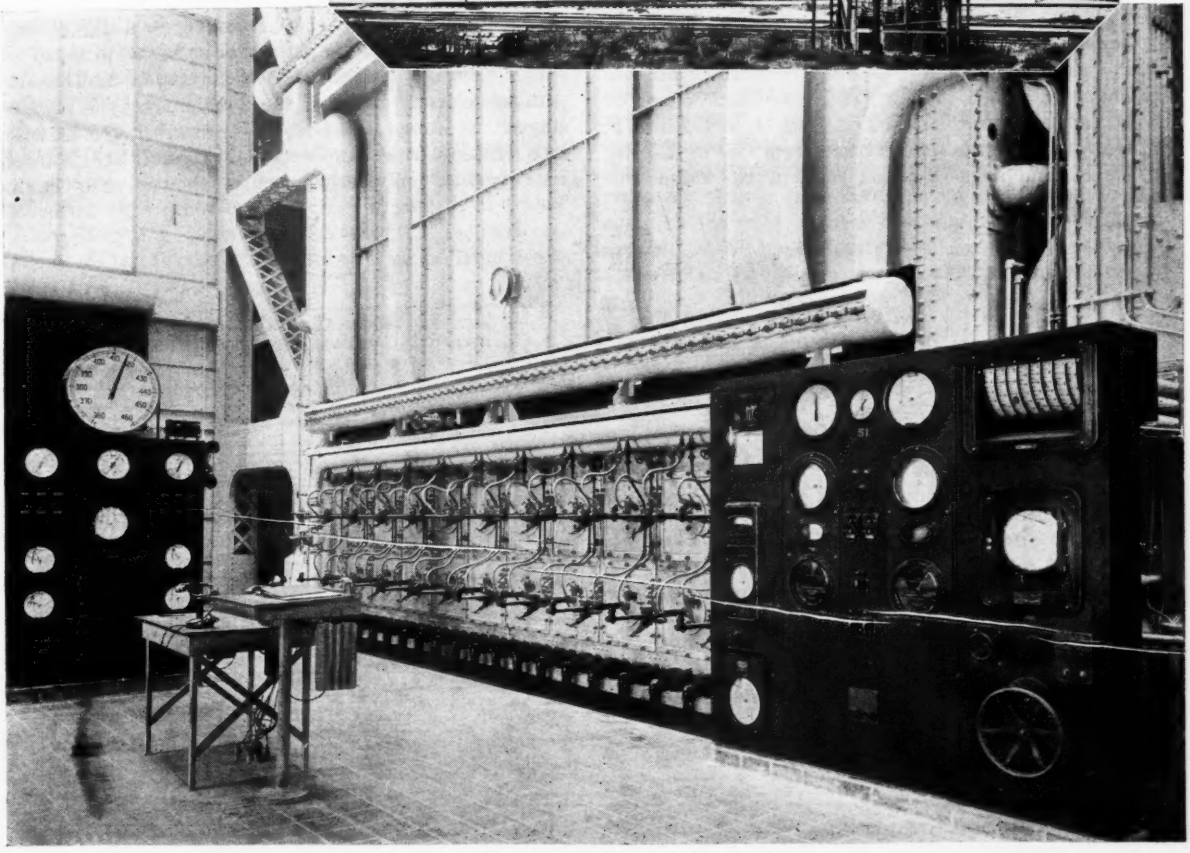
Barrels of fuel oil = (kw-hr. ÷ 500) + 150, the derivation of which is explained above.

According to the table, the total power generated July to November, 1928, was 213,097,690 kw-hr. in a total of 134 operating days. To generate this power according to the fuel economy equation, a total of 426,-192 bbl. of oil would be necessary for generation and 20,100 bbl. for standby, or a total of 446,292 bbl. of oil for the period. As compared with this estimated amount, fuel oil actually used amounted to 446,299 bbl.

Foregoing interesting performance has been obtained with an installation consisting of a turbine-generator

LONG BEACH





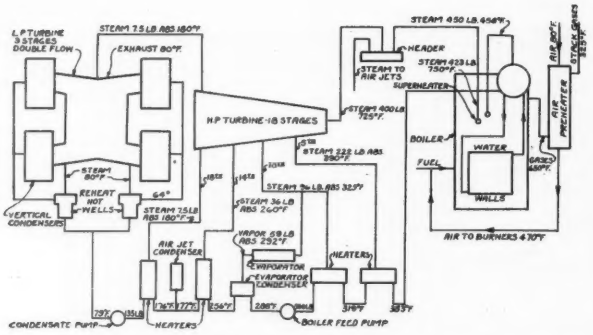


FIG. 1. HEAT BALANCE DIAGRAM FOR 100,000-KV-A. UNIT NO. 10, LONG BEACH STEAM PLANT NO. 3

rated at 90,000 kw. or 100,000 kv-a. with a 4000-kw. auxiliary generator, served with steam by three horizontal water-tube cross drum boilers of 34,168 sq. ft. of heating surface each, designed to furnish a maximum of 450,000 lb. of steam an hour each at 460 lb. pressure and 750 deg. total temperature.

As shown in Fig. 2, a cross-section through the entire station, boilers are of the interdeck type with a convection superheater of 6553 sq. ft. of heating surface between the decks of each boiler.

Each boiler has a furnace of 19,800 cu. ft., completely water-cooled, as shown, by tubes covered with refractory faced cast-iron blocks giving a total wall surface of 3240 sq. ft. Natural gas and oil can be used for fuels, burned in wide-range combination burners with insulated fronts, each boiler having 20 of these burners. Furnaces have been designed so that pulverized coal can be burned in them if it should ever become necessary.

Boilers are baffled for three passes of the flue gas, which passes through a 46,350-sq. ft. tubular air preheater behind each boiler. These preheaters are designed to heat air for combustion from 80 to 471 deg. F., reducing the flue gas temperature from 650 to 325 deg.

Forced and induced draft fans, of the radial-flow,

TABLE I. FUEL ECONOMY, LONG BEACH NO. 3, JULY TO NOVEMBER, 1928, INCLUSIVE, SHOWING COMPARISON OF COMPUTED AND ACTUAL FUEL CONSUMPTION

	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	TOTAL
K.W.H. Generated and Transmitted from Plant	15,685,200	40,467,500	46,025,700	56,096,050	54,823,240	213,097,690
Number Days In Operation	17	26	30	31	30	134
Estimated Fuel Oil Required according to Economy Equation:						
For generation at 500 K.W.H. per barrel	31,370	80,935	92,051	112,190	109,646	426,192
For standby 150 bbls. per day operation	2,550	3,900	4,500	4,650	4,500	20,100
TOTAL ACCORDING TO EQUATION:	33,920	84,835	96,551	116,840	114,146	446,292
Fuel Oil actually used, bbls.	33,750	84,525	96,519	116,983	114,522	446,299

FUEL ECONOMY EQUATION: For Generation - 500 K.W.H. per barrel of oil
For Standby - 150 Barrels of oil per day plant operated
Total Barrels of Oil = $\frac{\text{K.W.H.}}{500}$ + 150 Barrels Per Day

double-inlet type are located as shown on the deck above the preheaters. They are driven by alternating-current commutator type motors, with four control panels above the boilers as shown. Forced draft fans each have a capacity of 53,000 c.f.m. at 10 in. water pressure and induced draft fans each have a capacity of 180,000 c.f.m. at 7.3 in. of water. Arrangements for supplying feedwater will be discussed in connection with the turbine extraction heaters.

Attention Given to Piping Details

Seamless steel tubing forms the main steam piping; the steam header is forged from a steel billet and all joints in the high pressure piping will be of the Van Stone lap and Sarlun seal type. High pressure steam and water valves are 600-lb. standard with chrome nickel steel bodies and stainless steel stems and seats. Facings of the solid discs are of monel metal. Many of these valves are motor-operated.

Details of Turbine and Condensers

Turbine, shown in the headpiece, is a 125,000-hp., 1500-r.p.m. tandem-compound unit of a total of 21 stages, the high-pressure element having 18 and the low-pressure element being of the double-flow type in three stages. Steam pressure at the throttle is 415 lb. absolute, 725 deg. total temperature. The unit exhausts into four vertical condensers set as shown, each having

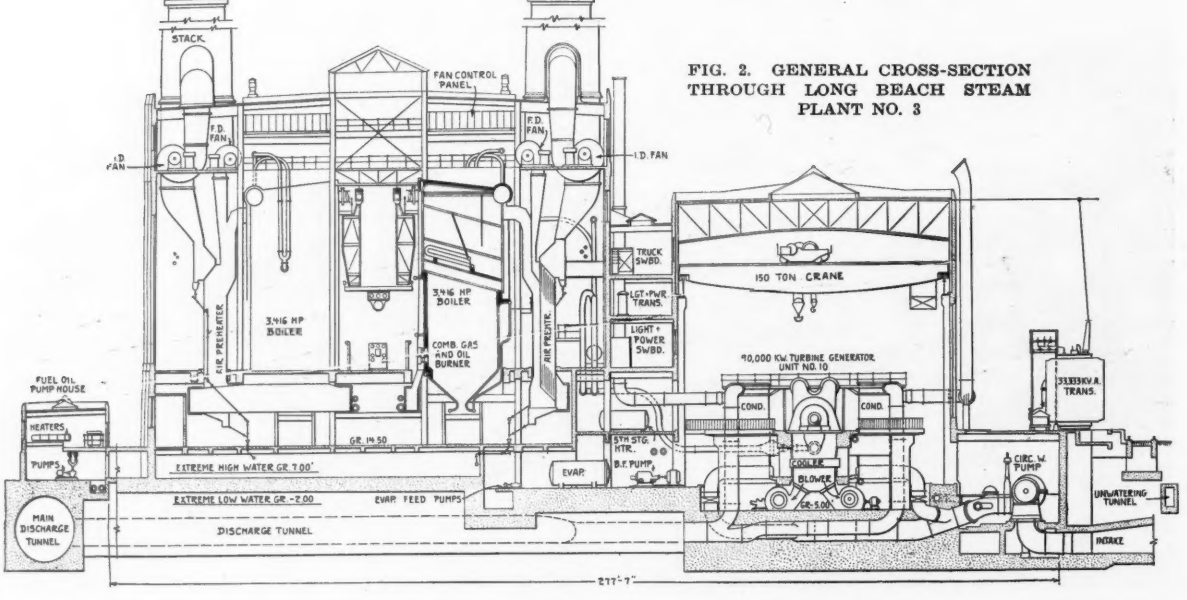


FIG. 2. GENERAL CROSS-SECTION THROUGH LONG BEACH STEAM PLANT NO. 3

TABLE II. OPERATING DATA FOR 132 DAYS, JULY 1 TO DECEMBER 6, 1928, ARRANGED IN 9 ZONES. KILOWATT-HOURS IN THOUSANDS

1 to 249 KWH	OIL	250 to 499 KWH	OIL	500 to 749 KWH	OIL	750 to 999 KWH	OIL	1000 to 1249 KWH	OIL	1250 to 1499 KWH	OIL	1500 to 1749 KWH	OIL	1750 to 1999 KWH	OIL	1750 to 1999 KWH	OIL	2000 & Above KWH	OIL
4	35	288	677	564	1,226	928	1,979	1,045	2,300	1,331	2,795	1,509	3,074	1,865	3,870	1,984	4,120	2,022	4,190
		326	900	687	1,440	987	2,044	1,028	2,178	1,329	2,747	1,605	3,295	1,828	3,800	1,909	3,960	2,063	4,260
				737	1,736	973	2,147	1,124	2,520	1,284	2,612	1,669	3,409	1,754	3,670	1,786	3,730	2,015	4,170
						793	1,742	1,039	2,077	1,262	2,536	1,662	3,410	1,829	3,820	1,782	3,725	2,039	4,230
						861	1,870	1,166	2,575	1,489	3,138	1,653	3,382	1,785	3,750	1,800	3,750	2,016	4,170
						892	1,993	1,185	2,570	1,388	2,960	1,644	3,381	1,829	3,825	1,907	3,958	2,012	4,153
						898	2,020	1,224	2,640	1,308	2,761	1,700	3,585	1,900	3,950	1,982	4,120	2,184	4,497
						932	2,090	1,158	2,520	1,366	2,810	1,670	3,453	1,870	3,898	1,984	4,110	2,156	4,440
								1,122	2,440	1,494	3,101	1,659	3,437	1,995	4,130	1,960	4,070	2,159	4,445
								1,123	2,460	1,478	3,043	1,729	3,640	1,899	3,940	1,945	4,030	2,130	4,390
										1,353	2,925	1,725	3,625	1,919	3,975	1,991	4,130	2,113	4,379
										1,468	3,150	1,637	3,460	1,807	3,770	1,916	3,942	2,136	4,425
										1,479	3,155	1,687	3,550	1,703	3,755	1,946	4,041	2,119	4,370
										1,326	2,880	1,575	3,325	1,995	4,135	1,767	3,720	2,017	4,169
										1,365	2,910	1,747	3,629	1,959	4,052	1,959	4,072	2,085	4,334
												1,719	3,595	1,905	3,960	1,978	4,080	2,005	4,145
												1,522	3,230	1,879	3,920	1,973	4,080	2,039	4,220
												1,726	3,610	1,930	4,002	1,887	3,920	2,062	4,260
												1,719	3,600	1,909	3,960	1,965	4,315	2,074	4,264
												1,509	3,210	1,952	4,050	1,910	3,960		
												1,658	3,470	1,803	3,760	1,911	3,920		
												1,504	3,200	1,894	3,930	1,886	4,130		
												1,620	3,410	1,829	3,810	1,995	3,920		
												1,553	3,275	1,945	4,030	1,887	3,810		
														1,955	4,050	1,825	3,960		
TOTAL 4	35	614	1,577	1,988	4,402	7,264	15,885	11,214	24,280	20,720	43,523	39,402	82,255			94,773	197,385	29,446	61,511
NO. OF DAYS 1		2		3		8		10		15		24				50		19	
AVG. DAY 4	35	307	789	663	1,467	908	1,985	1,121	2,428	1,381	2,901	1,642	3,427			1,895	3,948	2,076	4,290

20,000 sq. ft. of surface to condense 190,000 lb. of steam an hour each. The total steam consumption of the turbine at full load is 1,037,000 lb. per hr., part of which is extracted for feedwater heating. Cooling water flows upward in the condensers, making one pass; provision is made for reversing flow for washing. Reheat hotwells counteract the refrigeration of the condensate, and electrolytic equipment is installed to protect condenser tubes against corrosion. To prevent liberation of air in the circulating water, circulating pumps are set at mean low tide level. Two circulating pumps, driven by 2200-v. squirrel-cage motors, have a total capacity of 165,000 g.p.m.

Steam is extracted from the turbine at the 5th, 10th, 14th and 18th stages, giving corresponding steam pressures of 229,100, 36 and 7.5 lb. abs. Condensate from high-pressure heaters (5th and 10th stages) is trapped and sent to the flash tank, while condensate from the low-pressure heaters is discharged into the feedwater lines after the respective heaters. Figure 1, the heat balance diagram, shows the arrangement of heaters. Makeup water to the evaporators is taken from wells and treated in zeolite water softeners. Four boiler feed pumps are installed: two motor-driven, 2000-g.p.m., one turbine driven 1000-g.p.m. pump and one motor-driven 1000-g.p.m.

Generator and Auxiliaries

Generator is rated at 100,000 kv-a., 3-phase 16,500 v. 1500 r.p.m. On the end of the main shaft is mounted a 5000-kv-a., 2300-v. auxiliary generator, designed to furnish power for all station auxiliaries. The main generator feeds directly to a bank of three 33,333-kv-a. transformers outdoors, which in turn connects through the outdoor 220,000-v. switch-yard to the transmission line. Between generator and transformers are 16,500-v. high-speed oil circuit breakers for synchronizing purposes. Main and spare exciters are motor-driven, with a turbine on the main exciter for automatic pickup in emergencies. Both are separately excited by pilot exciters. Automatic control devices maintain generator frequency within close limits. An interesting feature in the switch-yard is the use of water sprays for washing the 220,000-v. insulators while in full operation.

Complete equipment for recording performance of

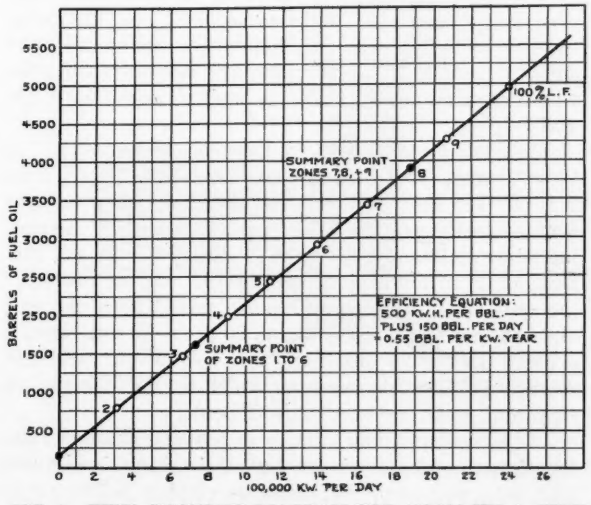
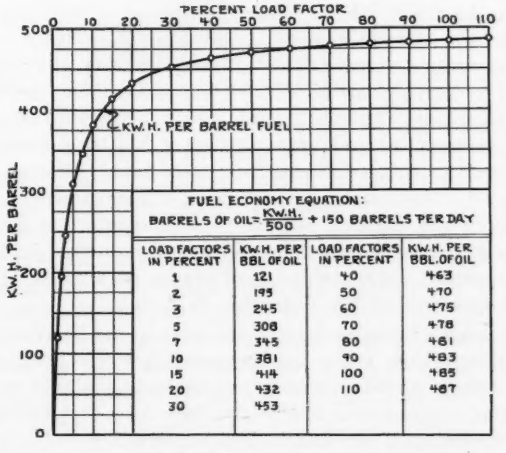

BARRELS OF FUEL OIL
100,000 KW. PER DAY
100% L.F.
SUMMARY POINT ZONES 7,8,+9
SUMMARY POINT OF ZONES 1 TO 6
EFFICIENCY EQUATION:
500 KW.H. PER BBL.—
PLUS 150 BBL. PER DAY
+0.55 BBL. PER KW. YEAR

FIG. 3. FUEL ECONOMY DIAGRAM FOR 100,000-KV-A. UNIT AT LONG BEACH



LOAD FACTORS IN PERCENT	KW.H. PER BBL. OF OIL	LOAD FACTORS IN PERCENT	KW.H. PER BBL. OF OIL
1	121	40	463
2	195	50	470
3	245	60	475
5	308	70	478
7	345	80	481
10	381	90	483
15	414	100	485
20	432	110	487
30	453		

FIG. 4. RELATION BETWEEN KILOWATT-HOURS PER BARREL OF OIL AND LOAD FACTOR, 100,000-KV-A. LONG BEACH UNIT

equipment in detail is provided: automatic combustion control system of the steam-flow air-flow-type, excess pressure regulators on boiler feed lines and all necessary meters and instruments. The view of the boiler room shows instrument boards and boiler controls.

Buildings housing the foregoing equipment have been specially designed to withstand earthquake shocks, with special arrangements to permit the stacks, furnaces, turbines and condenser foundations to resist such disturbances. Design and construction of Long Beach Steam Plant No. 3 was carried out by Stone & Webster, Inc., under the supervision of the Department of Engineering Design of the Southern California Edison Co.

Many Factors Cause Turbine Blade Failures

By W. E. Warner

BLADING FAILURES in turbines are caused by various factors, the most common probably being insufficient clearance or a shaft slightly bent during manufacture. This may, through time, get worse until it allows the blades to rub on the diaphragm and result in stripping. The diaphragms are also liable to distortion due to the pressure and temperatures they are subject to, which may be great enough to permit rubbing.

Vibration is also a frequent cause. Turbines are designed so as to avoid harmonic vibration at any speeds within the operating range. When a turbine is working under light load with only partial admission of steam, the intermittent blasts of steam cause rapid force fluctuations on the blading; this combined with any slight high frequency vibrations, the stress due to centrifugal force, and the stress due to the load carried, may cause fatigue of the blading material, and result in early failure. Fatigue fractures usually start from some surface imperfection, either due to the material or workmanship. A thorough inspection and a clean finish are therefore desirable.

Temperature Changes Should Be Gradual

Distortion of the diaphragms or blading is often brought about, when starting, by improper warming up. Starting up should be done slowly so as to avoid rapid temperature changes. The time specified by the makers for a starting up should on no account be reduced. Temperature changes brought about by sudden changes in the load or suddenly putting a machine from the condenser to the atmosphere also cause stresses and should therefore be avoided as much as possible. Although the balance may have been perfect when the machine was new, unbalance may afterwards occur due to unequal wear, stripping of blades or because of the displacement of the generator field coils.

Considerable wear can take place in the bearings and packing rings before it becomes otherwise noticeable; this is quite sufficient to cause serious unbalance which, under very adverse conditions, may lead to breakdown. Stripping of a few blades is not uncommon. The usual cause is moisture in the steam. Drops of water in the steam at the velocity at which it strikes the blades have force quite sufficient to rip out any blade. It is therefore advisable to pass the steam through a dryer and purifier before it enters the turbine, even with superheated steam. Of the blading troubles in turbines, 95 per cent is due to moisture or other impurities in the steam, the moisture ripping out blades and the solid impurities acting as a sandblast.

Reheating Sometimes Employed to Dry Steam in Last Stages

Solid impurities are often in steam, these being derived from scale dust carried over from the boiler, and metal particles and rust from the pipes. These impurities should be removed as they not only act as a sand blast but may cause valves to stick. The most efficient means of removing these solids is with a moisture separator or purifier. As the steam passes through the turbine, its temperature falls and in the last stages may be saturated with moisture. Drying or reheating between stages is usually adopted to remove the moisture as the temperature falls, this being the only way of removing this moisture.

The turbine should never be allowed to motor or be rotated from the generator end at a high speed for any length of time, as, steam not being present in the turbine, it would quickly cool down; owing to the fact that the correct clearance between the nozzles and blading is only maintained at steam temperatures, damage may be done due to the correct clearance not being maintained.

When a turbine has been shut down, all condensed water should be carefully drained off as any water left may cause rusting. This is more particularly necessary where steel blading is used, for any rust which forms will, when the turbine is next started up, be carried forward by the steam and act as a sand blast on the succeeding blades.

It is the practice in some plants to inject kerosene and light oil into the turbine with the steam just being shut down. This forms a film on the blades which protects them from corrosion. The oils are injected by a gun through nozzles near the admission valve.

Alabama Coals

In recent years, 20,000,000 t. of coal have been produced annually in Alabama some 60 per cent being washed to reduce ash and impurities, about half this amount being used to manufacture metallurgical coke, which requires that the coal be washed to minimize ash and sulphur.

Analysis by the Southern Experiment Station of the U. S. Bureau of Mines at Tuscaloosa showed ash from 2 to 15 per cent and moisture generally 2 to 4.5 per cent. Specific gravity varied from 1.26 to 1.37, increasing quite uniformly with the 2 to 15 per cent ash content. For mines having several thin partings between the coal veins, impurities become mixed with the coal and ash in a few samples ran to 20 per cent with specific gravity 1.42. To eliminate this ash would probably require considerable crushing which would increase the fines and make washing more difficult.

As a result of the study, it is felt that changes from the present elementary method of washing by jigging and screening could be made to yield a better grade of coal and smaller losses in the refuse.

Lubricant Reclamation

Reduces Power Station Upkeep

Part II* Purification by centrifugal means. Suggestions for installation and maintenance. Batch and continuous types of operation

CENTRIFUGAL purification is simply a precipitating action which is several thousand times more powerful than that of gravity alone and acts perpendicular to the axis of rotation, instead of vertically downward. Relative results are shown clearly in Fig. 1, in which the test tube at the left stood undisturbed for 24 hr. and the resulting separation was only partial while the mixture in the test tube at the right, which was subjected to strong centrifugal action for one minute, is completely separated; the lines of demarcation between the several layers are clear and definite. Water and fine impurities such as carbon particles are quickly and effectively removed from oil by centrifugal separators.

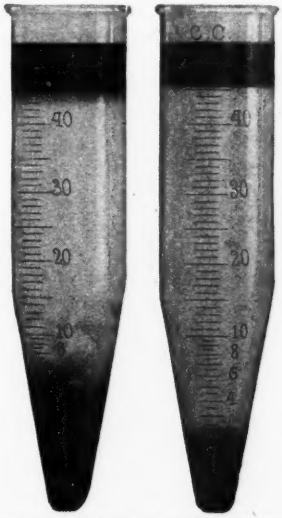


FIG. 1. RELATIVE SETTLING BY PRECIPITATION (LEFT) AND BY CENTRIFUGING (RIGHT)

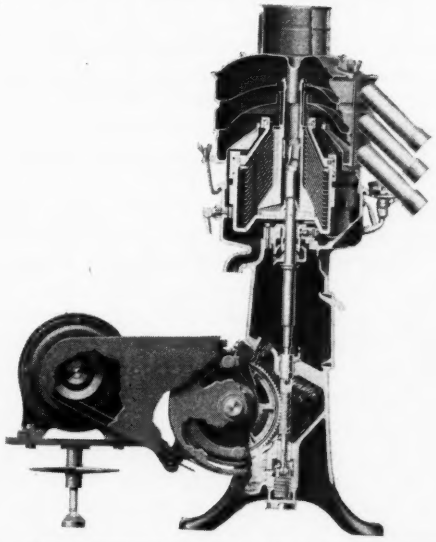


FIG. 2. CROSS SECTION OF DE LAVAL CENTRIFUGAL OIL PURIFIER

*Part I was published on page 347 of the March 15 issue.

Density of Substance Determines Its Position

Separation by the centrifugal machine illustrated in Fig. 2 is accomplished by rapid rotation of the bowl

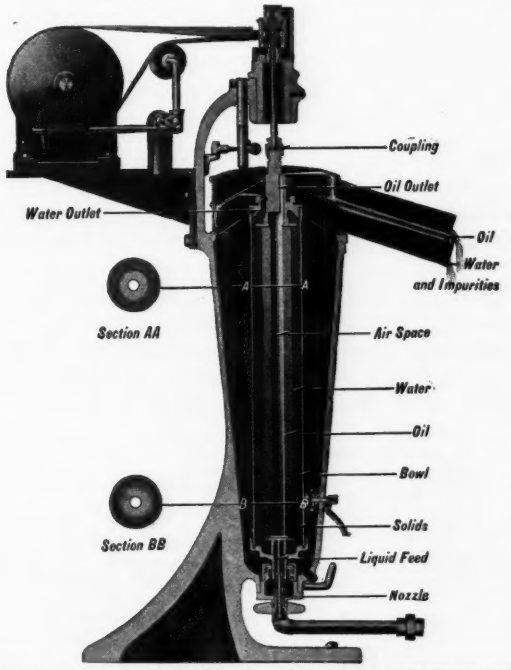


FIG. 3. CROSS SECTION OF SHARPLES CENTRIFUGE

as well as by the action of a series of superimposed disks. The dirty oil entering at the top flows through a strainer into the vertical funnel in the center of the machine to the bottom of the bowl which contains a number of conical purifying disks and rotates at a speed of from 6000 to 7000 r.p.m. The oil rises through the many spaces between the disks and is thrown off at the oil outlet. Heavy gravity dirt remains in the large dirt space surrounding the disks. Any water present passes around the edge of a water seal plate and is continuously discharged through the water outlet. Sufficient water must be poured into the bowl before starting normal operation in order to establish the water seal which prevents any oil from escaping around the edge of the water seal plate. In this separator, the driving

mechanism is below and the vertical shaft is guided in bearings at both top and bottom.

In the centrifuge shown in Fig. 3, the rotating bowl, which is a plain cylindrical vessel, is suspended from a ball bearing and is driven from above. The weight of the bowl is only about 37 lb. and its speed of rotation 12,000 to 15,000 r.p.m. The centrifugal force generated

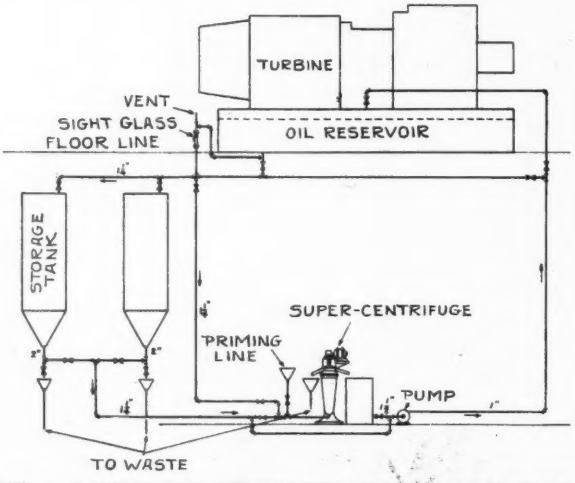


FIG. 4. LAYOUT FOR CONTINUOUS AND BATCH TYPES OF CLARIFICATION

in this centrifuge varies from 13,000 to 15,000 times the force of gravity according to the size of the machine. Inside of the bowl is a three-wing device whose function is to keep the liquid passing through the rotor from swirling.

Dirty oil is admitted at the bottom of the bowl, passes up through it and discharges from tinned steel covers at the top. The dirt or sludge and water are separated by centrifugal force from the oil as it passes through the bowl. The centrifugal action quickly forces

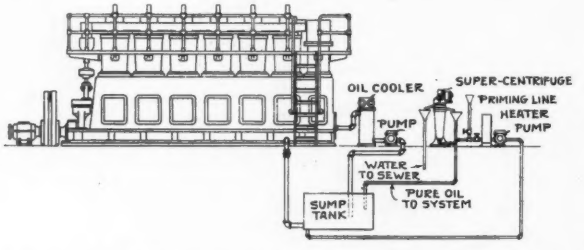


FIG. 5. LAYOUT FOR CONTINUOUS CLARIFICATION OF DIESEL ENGINE LUBRICATING OIL

the liquid to stratify into vertical cylindrical layers according to the specific gravities of those layers. Dirt and heavier particles are thrown out first and furthest, hence are collected later from the bottom of the bowl; the water assumes the central position and the purified oil the inner layer. The water and oil layers move upward as the rotation continues until each is removed through outlets which connect within the areas of these layers.

Two types of oil purification are employed. In the continuous type, 5 to 10 per cent of the oil used is by-passed through the purifier. This type is especially adaptable where the purification process used, such as a filter process, is not rapid. In the batch type of operation, all of the oil is treated at one time at periodic intervals depending upon operating conditions. By the use of twin storage tanks, the oil from one may be clarified while the other tank is connected in service.

Oil removed from crank cases, where splash lubrication is employed, is usually drawn off from small units into pails while large units may be connected by piping to a pump. The dirty oil may then be poured or discharged into an overhead barrel or tank whence it flows by gravity through a heater into the centrifugal machine.

Combination of continuous and batch types of clarification may be installed as shown in Fig. 4. The storage tanks at the left are used for batch treatment and storage of oil so that while the system is being drained of dirty oil, clarified oil may be pumped to the oil reservoir on the engine room floor and the purified oil

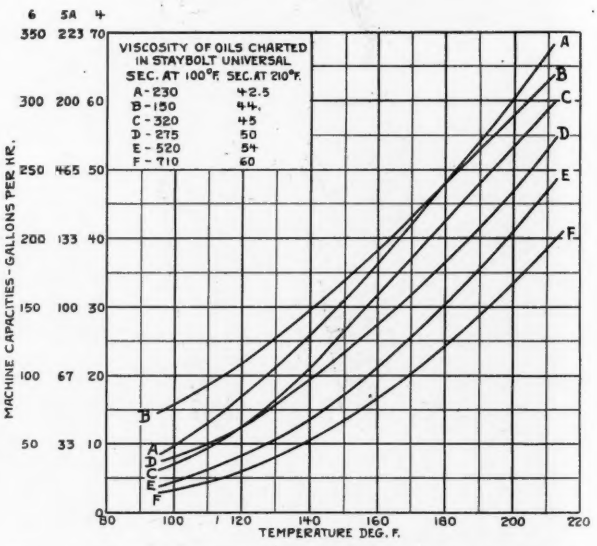

VISCOSITY OF OILS CHARTED IN STAYBOLT UNIVERSAL
SEC. AT 100°F. SEC. AT 210°F.
A - 230 42.5
B - 150 44
C - 320 45
D - 275 50
E - 520 54
F - 710 60
MACHINE CAPACITIES - GALLONS PER HR.
TEMPERATURE DEG. F.

FIG. 6. CHART SHOWING ADVANTAGE OF HEATING OIL BEFORE PURIFICATION

discharged from the centrifuge to the empty storage tank.

Continuous clarification of Diesel engine lubricating oil is illustrated in the typical layout Fig. 5. Oil is pumped from the sump tank through a heater to the centrifuge. Clean oil is discharged into a line returning to the sump tank from which it is pumped to the engine bearings. Solids removed from the oil are retained in the bowl to be cleaned out at the end of the run and water is discharged to waste.

If the purifier is installed at such an elevation that gravity flow of oil could be obtained from the engine to the purifier or from the purifier to the engine, one pump could be eliminated and installation would be simpler. If a gravity flow back to the engine is obtained, the usual collecting tank may be dispensed with.

Effectiveness of centrifugal purification is greatly increased by heating the oil before it is treated in order to reduce its viscosity. The temperature of the oil should be kept at from 160 to 180 deg. F. during the purification process. Heating is accomplished by steam, hot

water or exhaust gas, depending upon the availability of these agents.

Where exhaust gas from Diesel engines is used, the temperature of the oil is controlled by butterfly valves which regulate the amount of gas passing through the heater. Where this method is employed, there is some danger that the control valve may not be properly regulated and therefore allow too much gas to enter the heater and thus burn the oil. It is generally safer to use water to convey the heat to the oil through pipe coils. Chart, Fig. 6, illustrates the advantage of heating the dirty oil before centrifugal clarification. This chart was plotted for six representative oils and for three sizes of machines.

Installation and Operation

Efficiency of centrifugal clarification depends largely upon the manner in which the machine is installed and

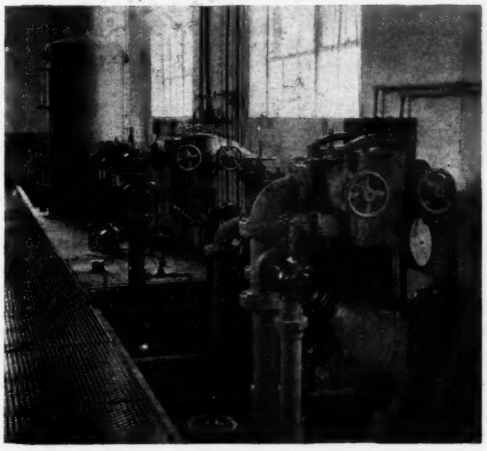


FIG. 7. FAIRBANKS-MORSE DUPLEX OIL STRAINERS INSTALLED IN LARGE DIESEL PLANT

operated. Effectiveness is increased when the capacity of the machine is ample so that the oil may be purified more often than otherwise. The oil should be drawn off from the bottom of the sump tank if a sump tank is used so that the dirtiest oil will be drawn off. Any system designed to handle two different grades of oil should be provided with sufficient precautions to prevent the two products from becoming mixed and therefore proper drain cocks should be installed at the lowest point on lines through which the oils are handled, particularly if the lines are long.

Dirt removed from the oil must be cleaned out of the bowl when the dirt-holding capacity is reached, otherwise purification will be affected and subsequent cleaning made more difficult. Regular cleaning periods should be established. Selection of the proper ring to be employed is an important matter. This can be done best by trying several different sizes for a given condition. The correct diameter of ring depends upon the relation of the specific gravity of the oil to be run to that of the water and on the temperature at which the run is made. If some water is discharged with the oil from the purified oil outlet of the machine, a ring of larger diameter should be used. If oil is discharged from the water outlet, a ring of smaller diameter should be employed.

Because of the high speed of the machine, lubrication is an important matter. Care should be taken to use the oil recommended by the manufacturer of the machine and to use it in sufficient quantity at all times.

Special Forms of Centrifugals Now in the Market

Centrifugal oil clarifiers of the portable type are also now in the market. Such clarifiers are often equipped with electrical heaters so that the entire process of clarification may be done at or near the source of dirty oil without the need of a piping system. Centrifugals acting about a horizontal axis are now also supplied. These are designed particularly for locomotive and similar service in order to withstand shocks such as are incident to coupling cars.

Errors in Electric Instruments

By W. E. Warner

IN A PROMINENT English laboratory, investigations were made into some of the minor inaccuracies in alternating current instruments, which revealed some unsuspected causes. Substation dynamometer type instruments were found to be affected by leveling errors. The errors in the instruments were so small that they were difficult to trace but after thorough testing, it was found that variations from level of 0.5 to 1 deg. will cause an inaccuracy of 0.2 per cent; for larger variations from level, the inaccuracy is greater. This shows the need for accurate leveling and for checking this from time to time, as bad leveling may easily develop in the ordinary course of operation.

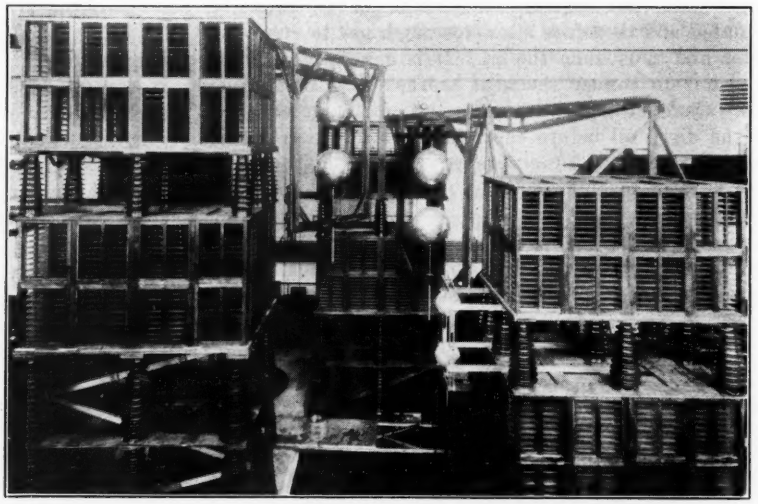
Another defect was found to be due to the insulating and adhesive varnishes used for impregnating the moving parts and for attaching pivots. These were found to be capable of considerable distortion, due to drying out and the trouble was found to be due to, and affected by, the atmospheric temperature, the humidity and the heating effect of the current. These errors were small and can only be eliminated by a development in manufacture.

In the case of alternating current wattmeters connected directly to the circuit, an appreciable error was found to be caused due to eddy currents induced in the winding of the current coil itself. These errors have been known previously and in the case of instruments employing coils wound with copper conductors of large section, these have been stranded in order to reduce the eddy currents but how small the strands should be to eliminate the eddy currents has not been known. These errors are not great on circuits of high power factor but when measuring on circuits of low power factor, the errors become considerable. The effect of eddy currents is equivalent to a short-circuited turn near the current coil, the eddy currents lagging behind the main currents.

These eddy currents may be very small and as they are approximately in quadrature, they have no appreciable effect when the power factor is high. As the power factor falls, these eddy currents come nearly into phase with the voltage of the circuit, and it has a greater effect on the accuracy of the instrument, more especially because the torque due to the true power in the circuit is reduced at low power factors. This effect varies with the frequency and causes serious errors at low power factors.

LIGHTNING

REAL and ARTIFICIAL



A review of progress made in the study of lightning and its effects upon electrical apparatus. Within the past few months, at the General Electric Co. laboratory an artificial lightning discharge of 5,000,000 v. has been obtained.

AMONG THE MANY interesting developments disclosed at the winter convention of the American Institute of Electrical Engineers held in New York, January 28 to February 1, one of particular interest to engineers in all branches of the field was that of the production of an artificial lightning flash of 5,000,000 v. The announcement of this achievement was made by F. W. Peek, Jr., of the General Electric Co. at Pittsfield, in connection with the presentation of a paper, by him, on recent progress in lightning research in the field and laboratory.

Progress in the mastery of lightning problems has been very rapid and while there is still much to learn, lightning may be said now to be at least on an engineering basis since it is expressed numerically in volts and amperes. It has been removed from the realm of the "medicine man."

Consider what has been accomplished. The wave shape of lightning has been pictured by the cathode ray oscillograph; the time required for a cloud to discharge has been measured by the same device; the attenuation of lightning waves traveling on a transmission line has been determined; natural lightning waves have been reproduced in the laboratory where their effects on transmission lines, insulators, transformer and protective equipment have been studied at will; a lightning generator producing over 5,000,000 v. has been constructed. Waves from generators of 3,600,000 v. have been sent over transmission lines to test full size transformers and other apparatus to determine how to make them highly resistant to lightning; scientific work on the time lag of gaps and insulation has been extended.

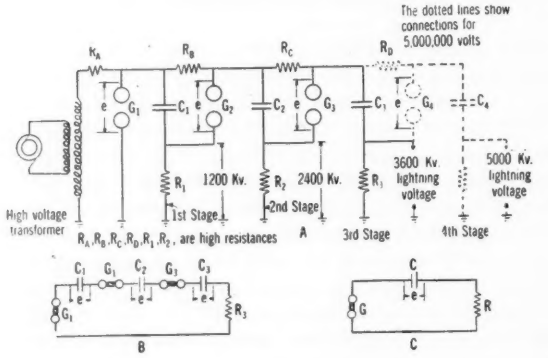


FIG. 1. CIRCUIT DIAGRAM OF LIGHTNING GENERATOR

Work on the lightning generator has been extremely interesting. Up to the early part of 1927 the laboratory lightning work had progressed so far that it seemed important to double the 2,000,000 v. available at that time. A 3,600,000 v. generator was built and just within the past two months 5,000,000 v. has been made obtainable. Double the directly generated voltages due to reflections have been measured at the ends of transmission lines.

Mr. Peek devised a radically new method of obtaining extremely high voltages. The effect is of adding two, three, four or more of the original generators in series at the proper instant so that all of the respective impulse voltages add together. No rectifiers are used. The a.c. voltage is applied directly to each unit generator. At that instant on the crest of the wave when each unit is fully charged, gap sparkovers take place that connect the generators in series and the impulse occurs. The connections are shown in Fig. 1A. The condensers of the three generators—C_1, C_2, C_3 are charged from the transformer to a crest voltage corresponding approximately to the G, gap setting. Sparkover occurs on G_1 followed immediately by sparks on G_2 and G_3. Resistance R_a, R_b, and R_c, R_1 and R_2 permit the small 60-cycle charging current to flow but are, in effect, infinite to an extremely high impulse current. The result is as shown in Fig. 1B. Only three gaps are in series on 3,600,000 v. and four on 5,000,000 v. One,

two, three, four or more steps can be used. The wave shape is determined by R, L, and C. Waves varying in duration from a few microseconds to a thousand microseconds have been experimented with. The maximum energy is about 14,000 watt-seconds. Figure 1C shows the original single-unit generator.

Measurement of High Voltage

Considerable skill and experience is necessary to measure high lightning voltages of very short duration.

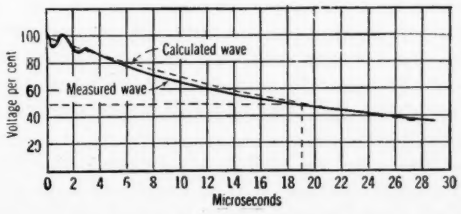


FIG. 2. LIGHTNING WAVE OF 3,600,000 V. LIGHTNING GENERATOR, CALCULATED AND AS MEASURED BY THE CATHODE RAY OSCILLOGRAPH

Such simple things as voltmeters, at least voltmeters in the ordinary sense, are out of the question. In the pioneer work, it was necessary to check the voltage measurements in a number of ways. The voltages were first calculated from the circuit arrangement; a check by 100 cm. sphere-gaps up to 1500 kv. was made, readings were taken with a surge voltage recorder or klydonograph; as a final method measurements up to the maximum voltage were made with a potentiometer.

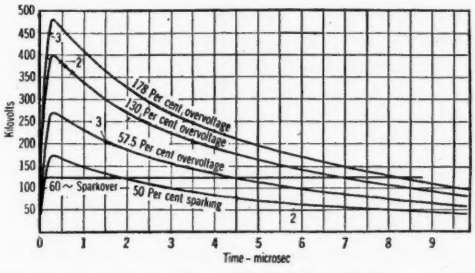


FIG. 3. SPARKOVER OF A POINT GAP WITH A CONSTANT WAVE SHAPE AT VARIOUS APPLIED VOLTAGES

Wave Shape

An extremely important element in lightning studies is the wave shape. In the first studies of transients, wave shapes could not be pictured directly; it was necessary to calculate them. The cathode ray oscillograph now affords a means by which oscillograms can be taken readily.

With the exception of gaps between electrodes producing a uniform field, that is sphere gaps, the lightning or impulse sparkover voltage is always appreciabiy higher than the 60-cycle sparkover voltage. The steeper the wave or the shorter the duration of the transient, the higher is the crest sparkover voltage. The lightning breakdown voltage will thus vary because lightning surges vary. The ratio of the lightning to the 60-cycle crest sparkover voltage is always greater than unity. Some years ago this was termed the impulse ratio. Under usual severe lightning conditions in practice, insulator sparkover voltages give an impulse ratio of two. This has been well established by comparing the lightning sparkover voltages of insulators as measured in the field by the surge voltage recorder and the klydonograph with the 60-cycle sparkover voltage. The impulse ratio is thus an indication of the effective duration of the wave. The wave in Fig. 2 gives an impulse ratio of two. The standard high-voltage laboratory wave was established before the field data were available. The laboratory lightning thus corresponds to the wave causing sparkover and damage in practice, for if the actual lightning wave were of effectively longer duration the impulse ratio could not be so high.

Whether the front or the tail of the wave is the controlling factor in determining the lightning sparkover depends upon the voltage applied. This is well illustrated in the oscillograms of Fig. 3 representing actual test records on a 19.9-cm. point gap. The same wave was used throughout these tests. In the first tests, the voltage was increased until sparkover occurred at 50 per cent of the applied impulses. An impulse wave with a crest voltage of 175 kv. was required for breakdown while the 60-cycle crest sparkover value for the same distance was 125 kv. The impulse ratio was accordingly 1.40. The actual sparking points on the wave are indicated by the crosses. An interesting fact was found here probably for the first time—namely, that sparkover actually took place after the tail of the wave had decreased below the 60-cycle value. Apparently the breakdown effect, once started by the overvoltage, continues, so that the spark actually forms after the wave has fallen below the minimum 60-cycle crest sparkover voltage. A wave of 57.5 per cent in excess of the minimum impulse sparkover voltage was next applied to the gap. As can be seen from Fig. 3, sparkover still took place on the tail at a higher value. Breakdown of the gap occurred on every applied impulse. With 130 per cent excess voltage, sparkover took place practically on the crest of the wave, while at 178 per cent overvoltage it occurred on the front of the wave. The corresponding impulse ratios for this short gap cover a range from 1.4 to 3.5. Figure 4 shows the variation in sparkover voltage with waves of the same front but with 5, 10, and 20 microseconds durations above the 60 cycle sparkover voltage.

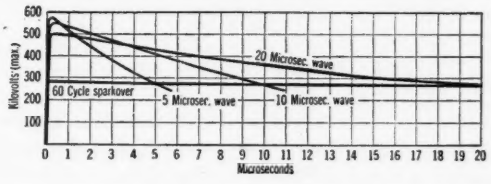


FIG. 4. VARIATION OF SPARKOVER VOLTAGE FOR WAVES OF 5, 10, AND 20 MICROSECONDS DURATION
50 cm. needle-gap—sparking 50 per cent of applied impulses.

In Fig. 5 is shown the effect of wave front on sparkover. Standard tests in the laboratory are made by gradually increasing the impulse voltage until sparkover occurs on 50 per cent of the applications. The instantaneous breakdown voltage when the front is relatively short then depends largely upon the duration of the tail as shown in Fig. 5 where the crest voltage is the same for the three waves.

An important development is the grading shield for insulators. The grading shield bears about the same relation to the insulator string as the ground wire does to the line. An important function of the grading shield is to cause even distribution along the string. This strengthens considerably the path along the insulator surfaces to lightning and forces the arc to take place between the rings which may be set for a lightning sparkover voltage higher than that of the non-shielded string. Destructive cascading is thus prevented. In this way the gain in voltage may be as much as 10 per cent to 12 per cent, and can be checked by comparing the lightning sparkover of the non-shielded string with the needle-gap lightning sparkover of the distance between rings. For the 20-microsecond wave this is

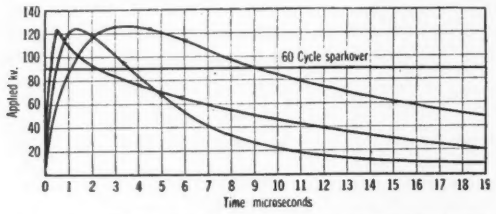


FIG. 5. EFFECT OF WAVE FRONT ON SPARKOVER
Sparkover of 13 cm. needle gap with given impulse ratio and different waves.
Crosses indicate average sparking range.

usually over 10 per cent. For very steep waves it may be more.

While the sparkover voltage of lightning waves may be increased by the shield, the 60-cycle sparkover voltage may be lowered. This is not a handicap because lightning surges having an impulse ratio of unity and thus corresponding to 60-cycle waves have never been observed in practice. The dry 60-cycle shielded sparkover voltage might be somewhat increased by using very large shield surfaces free from sharp ends or points; however, there can be no gain in practice in this way because the large surfaces would be reduced to equivalent "points" in 60-cycle voltages when wet by the first raindrop. Lightning sparkover voltage is not affected by rain.

To be successful, a shield must grade and increase the strength along the string so that sparkover is forced to occur between rings rather than over the surface of the insulators with the shield at the same time maintaining a high 60-cycle flashover voltage; that the design must be such as to dissipate the maximum energy by corona and thus have the effect of increasing the impulse sparkover voltage; that single sharp points or sudden surface changes are undesirable; that no practical gain results from large rounded surfaces.

From the standpoint of clearing the dynamic arc, complete round or oval rings are highly desirable as a track for the arc when blown by the wind. Anchor points at the ends of a sectionalized shield may cause it to wrap around the string.

Wood Poles

The insulating value of a wood pole to lightning voltages has been measured up to 3,600,000 v. The measurements show that the strength of wood poles of such varying degrees of wetness and dryness as might occur in practice, range from 100 to 300 kv-ft. A good average value is 180 kv-ft. Thus, a pole 35 ft. high, with a 5-ft. crossarm, would have a lightning sparkover voltage of $40 \times 180 = 7200$ kv. The insulator would add very little to a pole of this length; however, when the length of wood in series with the insulator is not over 10 ft., from 75 to 100 per cent of the insulator flashover voltage may be considered as added to that of the wood to comprise the total pole insulation. A practical example of this is a pole made conducting by a lightning rod to prevent splitting, with the insulation depending upon the insulator and crossarm. In a case of this kind, part of the insulation of the pole could be utilized and protection from splitting afforded at the same time by placing a gap in series with the lightning rod. To prevent splitting, the 6-3-1 ratio shown in Fig. 6 should be used.

Whether a pole is wet or dry makes very little difference on the lightning voltage necessary to cause complete flashover; however, when a pole is quite wet, incipient sparks will take place over the insulator string at voltages approximately equivalent to the lightning sparkover voltage of the insulator string above.

While wood poles without rods or ground wires may have very high lightning sparkover voltages, there is

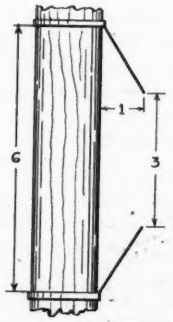


FIG. 6. PROPORTIONS FOR WOOD POLE PROTECTING GAPS

always a danger of long delays due to split and burned poles that could not be tolerated on important lines. The porcelain insulator is more reliable; however, by use of gaps as illustrated above, part of the insulating value of the wood may be used to advantage on certain secondary lines.

Measurement of Actual Lightning Waves

A portable cathode ray oscillograph, of the Dufour type developed by Mr. Lee and his staff of the General Engineering Laboratory of the General Electric Co., made possible during the past summer the measurement of wave shapes of actual lightning. In order to make proper use of the oscillograph, it was necessary to devise a means of establishing the cathode beam and the sweeping circuit and to have the complete set-up connected to the line as the lightning wave reached it. With the equivalent "switching circuit" developed for this, the complete operation was accomplished in about one microsecond—that is, one-millionth of a second. Part of the wave front would accordingly be lost unless special means were taken to prevent it. One way to accomplish this is to side track the wave around a loop about 1000 ft. long, requiring about one microsecond to travel it, and take it coming back; however, the

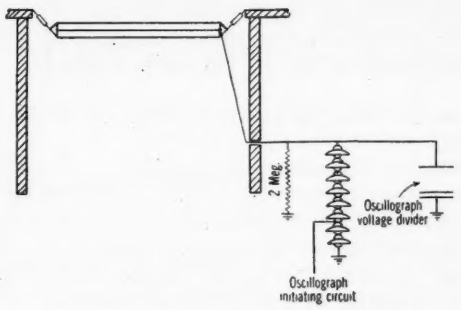


FIG. 7. METHOD EMPLOYED IN MEASURING NATURAL LIGHTNING VOLTAGES

results so far indicate that this refinement will usually not be necessary. The actuation of the oscillograph is done by means of spark "switches" controlled by the lightning surge. Connection to the line was made by an insulator potentiometer.

Measurements were made on short horizontal antennas and on actual transmission lines. The measurements of the antennas were made at Pittsfield while the transmission line measurements were made on the 220-kv. lines of the Pennsylvania Power & Light Company in coöperation with the engineers of the latter.

Pittsfield Measurements

In the Pittsfield measurements, the antennas consisted of three parallel wires 120 ft. long and 40 ft. above ground. The wires were grounded through a 2,000,000-ohm resistance and connection to the oscillograph was made as in Fig. 7. With this arrangement, the lines assume a potential opposite to that of the cloud when the lightning discharge takes place. Since the charge cannot move along this short line, but must be dissipated by leakage, the potential of the conductors rises at a rate and to a magnitude dependent upon the collapse of the cloud field. The time for this conductor voltage wave to reach maximum is thus a measure of the time required for the cloud to discharge. Figure 8 shows two of the four antenna waves obtained. The wave fronts are of the order of one to two microseconds. The induced voltage crests on the antennas were from 50 to 75 kv. The storm clouds in each case were at least a mile away. Such wave measurements, indicative of actual cloud discharges, are exceedingly helpful in determining the shape of surges themselves on trans-

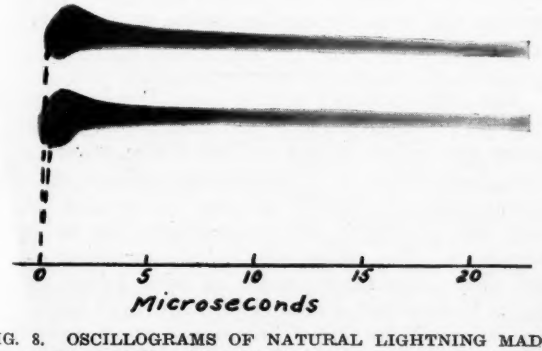


FIG. 8. OSCILLOGRAMS OF NATURAL LIGHTNING MADE ON SHORT LINES—PITTSFIELD, 1928. DRAWN DOTTED LINES INDICATE APPROXIMATE FRONTS
(Photo General Electric Co.)

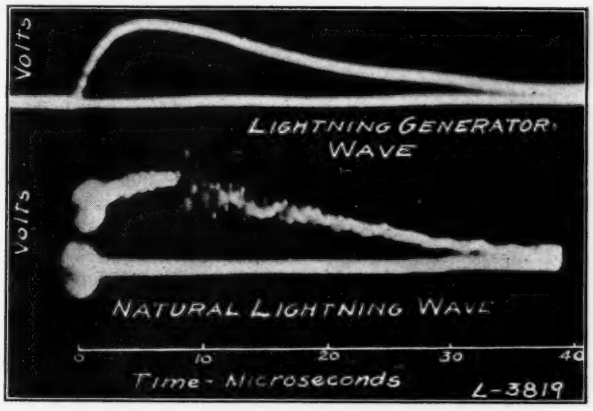


FIG. 9. COMPARISON OF NATURAL LIGHTNING WAVE MEASURED ON TRANSMISSION LINE WITH CATHODE RAY OSCILLOGRAPH WITH AN ARTIFICIAL LIGHTNING WAVE MEASURED IN THE SAME WAY
(Photo General Electric Co.)

mission lines. A mathematical analysis to correlate these field results with theory is now being undertaken.

Pennsylvania Measurements

A very good wave obtained on the 220-kv. line is shown in Fig. 9. The front of this wave practically reaches its maximum in 5 microseconds, decreases to half value in 20 microseconds, and reaches zero in 40 microseconds. The oscillating ripple is apparently due to a local flashover and is not really part of the original wave. A reproduction of this wave by the laboratory lightning generator is also shown in Fig. 9. The effects of the wave are very similar to the standard wave of Fig. 2 and the impulse ratio for insulator sparkover corresponds to those determined by the surge recorder or klydonograph readings.

Study of Direct Strokes

Figure 10 is an illustration of the method used in studying the effects of direct strokes. Photographs showed certain office buildings struck. An examination was made to see whether any of those hit fell within the protective cone of other buildings as established by

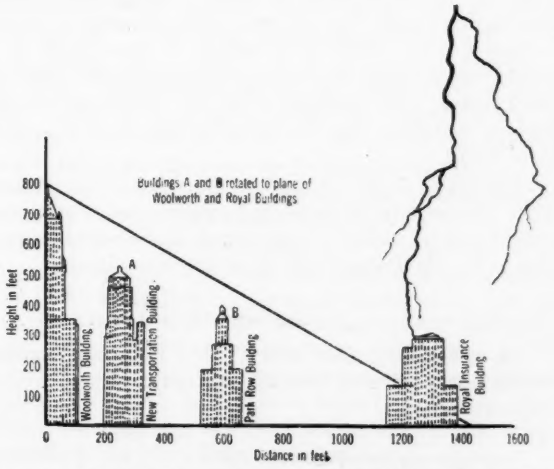


FIG. 10. LIGHTNING STRIKING BUILDING IN NEW YORK CITY. PROTECTIVE CONE IS NOT VIOLATED. FROM A PHOTOGRAPH ESTIMATED CLOUD HEIGHT 2800 FT.

former laboratory tests. It was found that they were in agreement with tests on models.

Lightning on Transmission Lines

A consideration of the foregoing in conjunction with former work shows that a fairly clear picture of what takes place during a thunder-storm is now available. It is reassuring that the great advances in research made during the past year tend to confirm and clarify what had already been done. Because of this advance in research, it seems desirable at this time to re-examine present transmission practice and see whether changes are desirable.

Voltage

The available data still confirm the rule that the maximum induced voltage on a transmission line depends upon the height of the conductors above ground. This would also apply in case of a direct stroke to the tower or ground wire where the conductor did not become involved. From the lightning standpoint, low towers with horizontal conductor spacings are desirable. The maximum voltage wave that can travel on the line and reach the apparatus is determined by the line insulation. The waves in practice are generally non-oscillatory and have a wide variety of shapes; however, the waves usually causing insulator sparkover give an impulse ratio of the order of two (2.0), and indicate an effective duration of 1 to 20 microseconds above the 60-cycle flashover value.

The distance that lightning can travel at high voltage on a transmission line is of extreme practical importance. The following table of data from the curve in Mr. Lewis' paper bears this out.

Lightning voltage k.v.	Distance of travel for reduction to half voltage (mi.)	Distance of travel for reduction to 0.80 voltage (mi.)
4000	1.5	0.4
3000	2.1	0.5
2000	3.0	0.7
1000	6.3	1.6

For example, 4000 kv. is reduced to half voltage or 2000 kv. in 1.5 mi. This indicates that the badly exposed section of a line normally insulated for 2000 kv. could be highly over-insulated without much danger of subjecting the normally insulated section to excessive voltages. It is only necessary to extend the highly insulated line several spans beyond the exposed section. It also indicates that moderate reduction of insulation at a substation, for instance, should not appreciably increase the outages. For example, 2000 kv. is reduced 20 per cent in traveling less than a mile and 50 per cent in three miles.

Statistical data still confirm the value of the ground wire. These data indicate that outages due to insulator arc-overs are reduced from one-half to one-tenth or more after the installation of the ground wire.

Summary of Characteristics of Lightning

In concluding his paper, Mr. Peek summarized briefly the characteristics of lightning. These are as follows:

Voltage—order of 100,000,000.
Current—order of 100,000 amp.
Energy—order of 4 kw-hr.
Power—order of 1,000,000,000,000 hp.
Time—order of a few microseconds.
Gradient at breakdown 100 kv-ft.

Time for cloud to discharge from one to 10 microseconds.

Discharge is generally non-oscillatory. Total energy dissipated in the world by lightning 1,200,000 kw. continuously (very approximate).

Characteristics of lightning on lines:

High voltage waves of few microseconds front and effective duration of 1 to 20 microseconds.

Low-voltage waves of much greater duration. Voltage either by induction or direct strokes.

Current in line for high voltage 2000 to 5000 amp. Voltages non-oscillatory. Attenuation very rapid for higher voltages.

Breakdown voltages higher than 60-cycle and impulse ratio for average high voltages, two.

Voltage increased directly as height of line—usual ground wires reduce to about one-half.

Transformer insulation should be stronger than adjacent line insulation.

Approximate lightning proof line seems feasible.

Laboratory voltages higher than ever observed on lines have been obtained and design tests made on full size apparatus.

Stack Computation—Correction

On page 320 of the March 1 issue, three typographical errors occurred. In the formula for diameter of stack, the figure 5 had dropped out. The formula should read $D = 0.39 \sqrt[5]{hp.^2}$.

In the list of resistances that make up the theoretical draft, the loss due to turns and that due to damper friction should be designated, respectively, H_T and H_D as indicated in the formula at the head of the list.

The hot-plate oil residue test involves the use of a simple domestic type of electrically heated hot plate. By means of a suitable voltage varying plug, the ultimate temperature to which such a plate will be heated can be controlled. That is of a special value where lubricants to meet varying high temperature conditions are concerned. The method of test is to bring such a plate to the requisite temperature and then deposit a drop of the proposed oil thereon. The resultant sludge or carbon residue which will remain after vaporization of the lighter, more volatile fractions which compose the lubricant will indicate the relative degree to which the product will probably develop carbon at that temperature in actual service.

The Indianapolis Power & Light Co., Indianapolis, Ind., has plans maturing for the construction of a superpower generating station on the White River, about 5 mi. from the city. It will be equipped for an initial output of about 160,000 hp., and is reported to cost more than $3,500,000, with transmission lines and accessory work. The latter will include switching station and power substation, connecting with a high voltage line to be constructed around the city. It is understood that work will be placed in progress at an early date. The company is a subsidiary of the Utilities Power & Light Corporation, Chicago, Ill.

Electricity---What It Is and How It Acts*

PART XXI. THE REAL SIGNIFICANCE OF THE ELECTRON'S JOURNEY IN THE VACUUM TUBE. EFFECT OF GAS UPON ELECTRON CURRENT. BY A. W. KRAMER

WHEN WE CONSIDER how very simple it is to evaporate electrons from a metal by heating it to a high temperature, it may seem surprising that the discovery of this phenomenon was delayed so long. The answer to this is, of course, that never until quite recently have we been able (even under this treating effect) to make the electron move fast enough in spaces

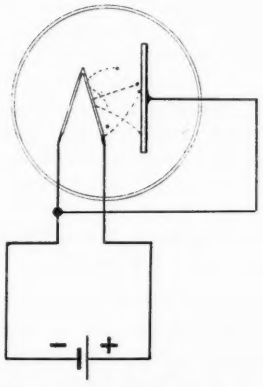


FIG. 1. CIRCUIT ARRANGEMENT TO SHOW KINETIC ENERGY OF ELECTRONS DUE TO TEMPERATURE OF THE FILAMENT

In this case, since the plate is connected to the negative terminal of the filament, it is at the same potential as the filament, consequently there is no electrostatic field. Any electrons reaching the plate do so by virtue of their own kinetic energy.

sufficiently empty of air or other gases. We have shown that, merely to escape from a solid metal, an electron must attain a speed of some 600 mi. per sec. Even with 10 times this speed it can move only a fraction of a millimeter through the air before losing its velocity and therefore, its power of going through the atoms. When Sir Wm. Crookes[1] first saw the cathode ray[2] stream its full course, it was because he had reduced the number of gas molecules in his bulb to such an extent that an electron could fly straight in a line from end to end of the bulb without going through more than perhaps a hundred atoms. Had there been air or other gas in the tube he never would have seen their effect, since their speed would have been destroyed in the first hundredth of an inch from the cathode.

So it was not until we were able to endow the electrons with high velocity and to free their path of nearly all atoms or molecules of gas that their effects became noticeable. It was under such conditions that Edison noticed their effect in imparting a charge to a plate within his lamp. While in Edison's lamp and in the rectifying tubes we have studied, the electrons are carried over to the plate by the positive potential imparted to the plate by an external electromotive force (the battery) it is possible, provided the vacuum is sufficiently high, for the electrons to fly to the plate under their own kinetic energy, that is, by the energy imparted to them by virtue of the temperature. To do this, they must have an exceedingly high initial velocity since it was shown that at normal operating temperature of a tungsten filament (2400 deg. C. abs.) only 1/8000 of the electrons emitted reach a distance of 0.15 cm. from the filament.

KINETIC ENERGY OF EMITTED ELECTRONS

John H. Morecroft of Columbia University, in experiments[3] along this line, found that a plate current existed in a tube even when the plate was at the same potential as the lowest potential point in the filament. A cold metal plate close to the filament was connected to the filament outside the tube as shown in Fig. 1; that

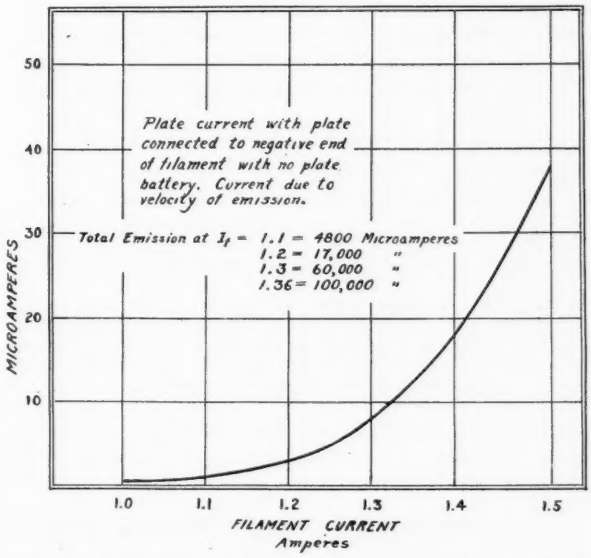


FIG. 2. ELECTRON CURRENT FROM A HOT TUNGSTEN FILAMENT TO AN ADJACENT COLD PLATE AT THE SAME POTENTIAL AS THE LOWEST POTENTIAL OF THE FILAMENT. CURRENT DUE ENTIRELY TO VELOCITY OF EMISSION OF ELECTRONS

is, the plate was connected to the *negative* terminal of the filament. Under these conditions, Edison, it will be remembered, found no current. This, however, was due to the fact that the plate in Edison's lamp was too far from the filament and the temperature of the filament probably was not high enough; the vacuum in his lamp, also, probably was insufficient. In Morecroft's tube, the plate was 0.2 cm. from the plate and the vacuum was such as is obtainable today with improved exhausting equipment. The plate current observed was measured, of course, in micro-amperes (millionths of an ampere), and was due entirely to electrons emitted from the filament, with such a high velocity that their inertia actually carried them across the 0.2 cm. space separating the plate from the filament.

Figure 2 is a curve obtained by Morecroft, showing

*All rights reserved.

[1]See Part I, May 1, 1928, issue, p. 509.

[2]Part XV, January 1, 1929, issue, p. 66.

[3]J. H. Morecroft, Principles of Radio Communication, p. 441.

how the plate current due to this effect increased as the filament current and consequently the filament temperature, was increased. The total emission of electrons from the filament (that is, the number actually leaving the surface but *not necessarily reaching the plate*) expressed in terms of microamperes is given above the curve. With a filament current of 1.3 amp., the total emission is 60,000 microamperes. Since an ampere, we learned,[4] is a flow of over six billion billion (6.28×10^{18} or 6,280,000,000,000,000,000) electrons per second, a micro ampere is a flow of $6.28 \times 10^{18} \div 10^{6}$ or 6.28×10^{12} electrons per second. Therefore, with an emission current of 60,000 microamperes at 1.3 amp. filament current, the total number of electrons evaporated per second is $60{,}000 \times 6.28 \times 10^{12}$ or 3.768×10^{17}.

The plate current corresponding to this filament current (1.3 amp.) it will be noted from the curve is 7.2 microamperes, therefore, the number of electrons reaching the plate every second is $7.2 \times 6.28 \times 10^{12}$ or about 4.5×10^{13}.

Thus out of some 4000, million million electrons boiled out of the filament, about 45 million million or

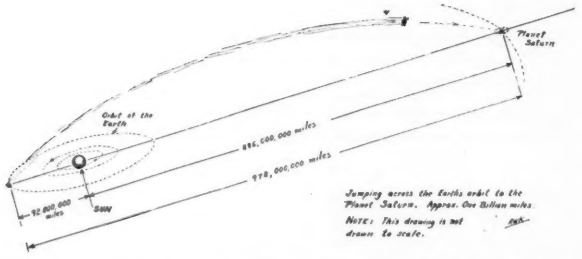

Planet Saturn
Orbit of the Earth
886,000,000 miles
92,000,000 miles
SUN
Jumping across the Earths orbit to the Planet Saturn. Approx. One Billion miles
Note: This drawing is not drawn to scale.

FIG. 3. IF A HUMAN BEING WERE TO JUMP THE SAME DISTANCE IN PROPORTION TO HIS SIZE AS THE ELECTRON DOES IN THE VACUUM TUBE, HE WOULD HAVE TO JUMP ONE BILLION MILES OR ROUGHLY TEN TIMES THE DISTANCE OF THE EARTH TO THE SUN

1⅛ per cent are endowed with sufficient velocity to carry them across the 0.2 cm. separating the plate from the filament.

The Real Significance of the Electron's "Jump"

Now two tenths of a centimeter, according to our standards of measuring distance, is not much. It is, roughly, 0.08 of an inch and it would seem that no great expenditure of energy on the part of an electron would be necessary to enable it to jump that distance.

Suppose, however, that we look at this feat (of jumping two millimeters) from the point of view of the electron; in other words, let us compare this distance with the size of the electron to determine how many times its own length or diameter the electron must jump.

While it is rather meaningless to refer to the size of an electron since we do not know whether an electron has such a thing as size or not, from collision experiments it can be shown that the electron's active sphere of influence is roughly a five million millionth of a centimeter. To jump two tenths of a centimeter, therefore, an electron must cover $0.2 \times 5{,}000{,}000{,}000{,}000$ or one thousand billion times its own length, let us say.

To realize what this means, let us suppose that we as human beings were to jump the same distance in terms of our length. The average individual is just about 1/1000 of a mile long. Therefore, in jumping one million million times his own length, a human being would have to cover $1{,}000{,}000{,}000{,}000 \times 0.001$ or 1,000,000,000 miles or approximately ten times the distance which separates the earth from the sun!

An electron, therefore, in going from the filament to the plate in a vacuum tube undertakes a journey of considerable distance, and it is not to be wondered at that if any large number of obstacles beset its path, its chances of reaching its destination would be small indeed. For this reason, it is very essential that all air be exhausted from the tube.

In spite of our utmost efforts in this respect—even with the highest vacuum it is possible to produce with the most modern equipment, there will still be a tremendous number of gas molecules in the evacuated space. In the highest vacuums used today (10^{-8} mm. of mercury) there are still about one hundred million gas molecules per cubic centimeter. So, even with such vacuums, the electron must traverse hundreds of atoms to reach the plate. Apparently, since atoms can be traversed in this way, they must be very empty affairs.

Effect of Electrostatic Field Between Plate and Filament

So far, in this particular article, we have considered the electron making the journey to the plate entirely under its own kinetic energy. In the practical vacuum tube, however, as we have learned in the previous articles, the electron is impelled toward the plate as a consequence of the electrostatic field between the elements of the tube produced by an external source of positive potential. Under these conditions, its speed is very much greater than when moving under its own kinetic energy. With 100 v. positive potential on the plate, a velocity of some 6000 mi. per sec. is acquired while with 10,000 v., as is used in radio transmitting tubes and x-ray tubes, the speed acquired by the electron is over 30,000 mi. per sec.

Now, what becomes of the energy expended in accelerating the electrons in this manner? In our first illustration, that is, where the plate was connected to the negative lead of the filament, the electrons managed to reach the plate by virtue of the kinetic energy they gained in the thermal agitation of the molecules in the filament. In this latter case, however, an external source of potential is used to draw the electrons to the plate and since we know that when a charge moves under the influence of an electrostatic field, it does so at the expense of the energy stored in that field, the question arises, what becomes of that energy?

To answer this, we have merely to consider the further consequence of the electron's rapid flight to the plate. We know, from experience, that when a rapidly moving object is suddenly brought to rest, the kinetic energy of the object is usually converted into heat energy. When a bar of iron, for instance, is hammered upon vigorously, it (and also the hammer) will become heated. Similarly, where the course of a swiftly moving bullet is suddenly brought to rest by a steel plate, the temperature of the steel at the point of impact will be raised—the amount of heat produced being the equivalent of the kinetic energy of the bullet at the time of its impact.

[4]Part XVIII, February 15 issue, p. 251.

In this same way, when a swiftly moving electron is suddenly stopped by a metal plate, the kinetic energy of the electron is transformed into heat. True, the mass of an electron is inconceivably minute but we have seen that at the moment it impinges against the plate it may be moving at velocities of anywhere between 1000 to 30,000 or more miles per second; its kinetic energy, therefore, despite its small mass, is considerable. The result then, of a stream of electrons impinging against the plate of an electron tube, is to raise the temperature of the plate. In vacuum tubes used for power purposes in radio, the electron bombardment is so great that in ordinary operation the plates are heated to a dull red heat. If the plate voltage on such tubes is raised to a sufficiently high value, the intense bombardment will heat the plate to a white heat in a few seconds, resulting in the destruction of the elements.

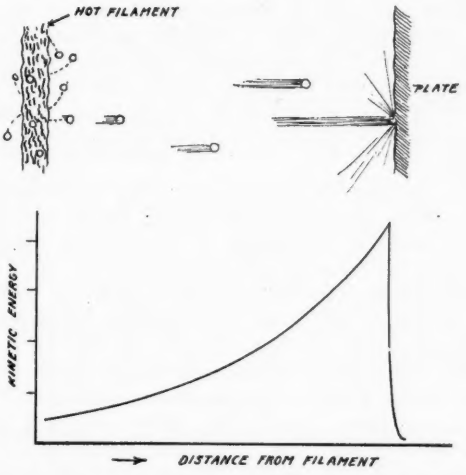


FIG. 4. DIAGRAM AND CURVE SHOWING HOW VALUE OF THE KINETIC ENERGY OF AN ELECTRON VARIES IN ITS COURSE FROM THE FILAMENT TO THE PLATE

At the point where the electron leaves the filament, its store of kinetic energy is low. As it moves towards the plate, however, its store of kinetic energy gradually increases until, just as it collides with the plate, it is a maximum. Here, upon collision, the kinetic energy is converted into heat and as the electron enters the plate, its kinetic energy falls practically to zero.

Heating of Plate Equivalent to Heating of Solid Conductors by Passage of Current

This heating of the plate in an electron tube is equivalent to the heating effect due to resistance in a solid conductor. We have seen, in Part IX[5] of this series that when an electric current is passed through a solid or liquid conductor, the movement of electrons among the molecules and atoms of the solid increases the molecular and atomic agitation, resulting in what we recognize as heat. In the vacuum tube, when we cause an electron to move to the plate we are supplying energy to it, but as long as its path remains clear and it meets with no obstacles, this energy will remain with it (the electron). Upon colliding with the plate, however, nearly all of this kinetic energy of the electron is converted into heat.

In the electron tube, therefore, there is thus a permanent expenditure of energy on the part of the plate battery similar in nature to that due to ohmic resistance of a metallic conductor. The energy supplied by the plate battery serves the useful purpose of attracting the electrons to the plate so that they may deliver their negative charges to it and thereby produce a current in the external plate circuit, but the energy from the battery which is represented by the motion of the electrons is permanently lost in heat at the plate as a result of the collision. It is evident, then, that the energy loss is directly proportional to the electromagnetic energy of the electron moving in the empty space of the tube.

From the above explanation, it is seen that the action of the electron in the vacuum tube is subject to the same laws that govern its action in solid and liquid conductors. In the solid conductor, the energy imparted to the electrons by the electrostatic field is given up with each of the numerous collisions with the atoms of the conductor. The distance through which a free electron in a conductor can move without colliding with an atom is comparatively short. In the vacuum tube, however, we have seen that an electron may travel hundreds of billions times its own diameter, without danger of colliding with many atoms, and for this reason all the energy supplied to it in the course of its travel from the hot cathode to the plate is retained until the instant the electron collides with the plate.

Effect of Gas in a Vacuum Tube

Thus far, in our consideration of the action of the electron in a vacuum tube, we have assumed that the space between the hot filament and the plate is free of all atoms of gas or air; in other words, we have assumed a perfect vacuum.

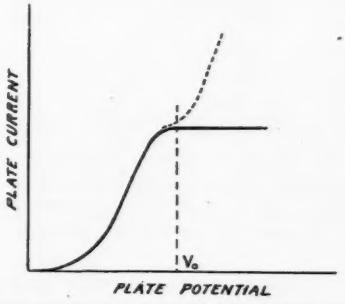


FIG. 5. CURVE SHOWING EFFECT OF IONIZATION OF GAS UPON THE PLATE CURRENT

Normally, with no gas present, the plate current curve is that shown by the full line curve, the saturation point being reached at the potential Vo. With gas in the tube, however, when the potential Vo is attained, ionization starts resulting in the increase of plate current shown by the dotted line curve.

This, however, is a condition quite unattainable, for no matter how well we exhaust a tube even with the most modern equipment, there will still be a large number of gas molecules or atoms in the tube. The effect of these few remaining molecules in the ordinary action of the tube is quite negligible.

Suppose, however, that there is a larger amount of gas in the tube. What will be the consequences? The early types of vacuum tubes were not well evacuated and there was often a considerable amount of gas (compared to modern practice) left in them which made their behavior erratic. Not only would various tubes, supposedly similar, have widely different characteristics

[5]Sept. 15, 1928, issue, p. 995.

but the same tube would act differently at different times. The reason for this was found to lie in the presence of the gas within the tube.

In the high vacuum tube, so far considered, the only current passing between the filament and the plate was due to electrons which were actually evaporated out of the filament. The space between the filament and the plate was not a conductor and the electron current was in no way dependent upon the nature of this space as long as it was devoid of atoms and molecules.

Suppose, however, that we introduce some gas into this space. Ordinarily, gas is a good insulator and will not carry current but when under rather low pressures it may be made to carry large currents, if by some means it becomes ionized. This, it may be recalled, was explained in Part VI[6] of this series, in connection with the theory of conduction through gases.

By ionization, we mean the breaking up of a gas

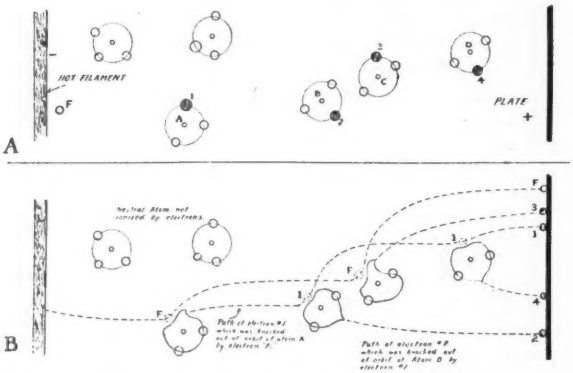


FIG. 6. DIAGRAM TO SHOW HOW IONIZATION BY COLLISION INCREASES THE VALUE OF THE PLATE CURRENT

At A is depicted crudely the position of a number of normal atoms of gas between the filament and the plate of a vacuum tube, each atom having one of its electrons designated by a number, 1, 2, 3, etc. At B is shown the condition after the electron F has collided with some of these atoms, the dotted lines showing the paths of the different electrons after they had been knocked out of the atoms. Instead of only one electron reaching the plate as would have been the case had no gas been present, five electrons are shown reaching the plate—the original electron emitted by the filament, and the four knocked out of the atoms.

atom into two parts, a free electron, and a positively charged ion (that is the normal atom with an electron removed). This, as explained in Part VI, is often the result of a collision between a high speed electron and an atom.

Now it is evident that if there are gas molecules or atoms in the path of the electrons journeying between the filament of a vacuum tube and the plate, there will be numerous collisions between the atoms and electrons, and if the velocity of the latter is sufficiently high the impact of collision will disrupt the atoms. This splits the atoms up into free electrons and positively charged ions, which travel, respectively, toward the plate and the filament producing an increase in the plate current.

This action is shown in Fig. 5 where the dotted line curve shows an increase in plate current after the ionization voltage V_o is reached. Normally, without any gas in the tube, the plate current would not increase after the potential V_o was attained, but with gas in the tube, when V_o is reached, the velocity of the electrons is high enough to cause ionization of the gas atoms.

Since the electrons leaving the filament are gradually accelerated as they near the plate, they attain their maximum velocity upon reaching the plate, naturally we would expect ionization to begin in the immediate vicinity of the plate and this is actually the case. As the voltage on the plate of a vacuum tube containing gas is increased, a blue glow will first appear around the plate. This blue glow is the direct result of ionization. It is the result of recombination of certain of the ionized atoms; that is, after an atom has been ionized, it may, before travelling very far, recombine with another free electron, forming once again a neutral atom. This phenomenon will be treated in detail in a subsequent article.

The ionization effect in vacuum tubes is cumulative. Suppose an electron is knocked loose from an atom by collision with a high velocity electron travelling toward the plate. The newly freed electron will at once be acted upon by the field or will be accelerated toward the plate. As it gains velocity, this electron in turn will ionize another atom and so on. Thus, in a short interval of time, there will be a very large number of free electrons in the tube, causing a large increase in current.

This process of ionization, while detrimental to the operation of vacuum tubes used in radio work, is used to excellent advantage in the case of rectifying tubes such as have already been referred to. In the Tungar rectifier, the tube is filled with an inert gas (usually Argon, at about 2 lb. absolute pressure) and this gas is ionized by the electrons, emitted by the hot filament. The carrier of the plate current is in this case mostly ionized gas, the number of electrons emitted from the filament being sufficient to carry perhaps 1/500 of the current to the plate. Tubes of this type are used only in low voltage work. Where high potentials are to be rectified, the tubes are usually made with as high a vacuum as it is possible to obtain and the plate current is never higher than that actually emitted by the filament.

Before we conclude this discussion of the effect of gas upon electron currents, it may be well to explain briefly, what becomes of the positive ions, produced by the collision between electrons and neutral atoms. As already mentioned, these are drawn toward the hot filament, due to the fact that it carries a negative charge; but since these positive ions are many thousands of times large than the electrons, their progress is proportionally slower. Nevertheless, if the potential gradient is high enough, these positive ions will also gain sufficient velocity to ionize other neutral atoms, resulting in still another increase in current.

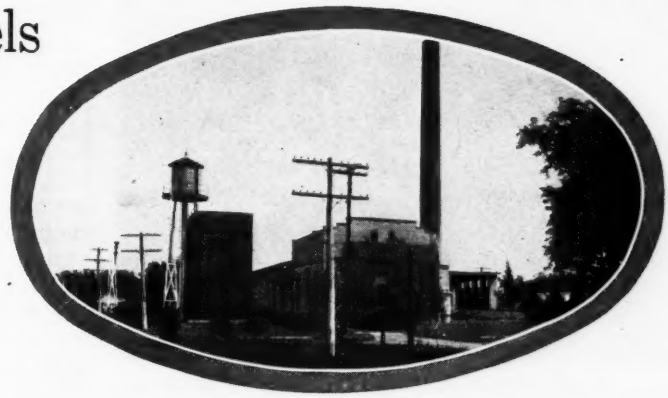
So it is evident that the effect of gas in a vacuum tube is quite important not only because of its beneficial or detrimental effect in actual tubes, but because of the insight which a study of the phenomenon affords us in understanding the role of the electron in other processes.

ELECTRIC POWER has been successfully applied to protect crops from insects. One successful installation consists of electric lights placed 6 in. above pans of kerosene. Insects are attracted to the light and eventually fall in the pans. Three pans to the acre placed about 10 ft. above the ground are used. This should be a stimulus to rural electrification in many districts.

[6]August 1, 1928, issue, p. 828.

Installation of Diesels Overcomes Water Supply Troubles

Cooling Tower and Special Water Treatment Provide High Quality Water for Diesel Engines That Replaced Steam Plant



LIMITED supply of water was the major feature of the power problem at the municipal power and light plant in Rochelle, Ill. Water is obtained from three wells, one 1980 and another 1026 ft. deep, each delivering 270 g.p.m. by the air lift process and one well 1484 ft. deep which supplies 560 g.p.m. through the operation of an American deep well turbine pump. Another well 1450 ft. deep, which is to supply an additional 560 g.p.m., has recently been drilled.

One 10 by 12-in. Ingersoll-Rand air compressor having a capacity sufficient to lift 200 g.p.m. and a 16 by 16-in. Norwalk air compressor with a capacity of 275 g.p.m., supply the necessary air lifting power to serve the deep wells.

Concentrate in Cooling Water Causes Trouble

Hardness and high content of incrusting material represented the principal difficulties regarding quality. Tests of the raw water show 20 grains of hardness per gal., 18 of which consist of incrusting material. Concentrate in untreated water in the cooling system, due to evaporation, is considerable. Different methods of treatment were tried and it was found necessary, due to the rapid concentration, to use a method that removed the hardness material and did not simply change such material in form.

FIG. 1. HOT WELL WHICH RECEIVES ALL COOLING WATER FROM ENGINES IS SUPPLIED WITH AUTOMATIC CONTROL

Recirculation of cooling water, addition of a cooling tower and treatment of makeup cooling water for the removal of hardness material before the water entered the system were then employed. The treatment, which was specially prescribed by the Dearborn Chemical Co., is carried on in part of the circulating system.

All cooling water coming from the engines flows into a 1000-gal. hot well located beside the engine room as shown in Fig. 1. Two American Well Works gravity fed, motor-driven centrifugal pumps which are set under the engine room floor, pump the water through a 4-in. pipe, which, due to its large size, avoids any collection of air pockets, over the cooling tower, shown in the headpiece. When the height of the water in the hot well is at its low limit, a float operates a General Electric Co. float switch, located on top of the well, which automatically shuts off the motor and when the water rises to an upper limit, current is again automatically thrown on. The gage board shown, which may be seen from the window, indicates the height of water in the hot well.

Bypasses Permit Control of Temperature

Baffles of cypress, creosoted pine structural timbers and galvanized iron fittings make up the cooling tower which was built by the Water Cooling Equipment Co. This tower, which is of the louver type, is 28 by 18 ft. in dimensions and 30 ft. high and has a cooling capacity of 400 g.p.m. from 140 deg. to 85 deg. Arrangement of piping permits pumping the water to three different heights, depending upon the outside temperature and the load carried, so as to maintain a temperature of from 85 to 90 deg. Normally, it is pumped to the top; during 10 deg. temperature, it is pumped only about halfway up and during zero weather the water issues from the pipe at the lower end of the tower. With small loads, more water is bypassed than with full load.

Dropping down over the baffles, the water finally reaches a 2600-gal. concrete catch basin from which it is pumped to an overhead 5000-gal. cypress wood tank by duplicate 300-g.p.m. American centrifugal pumps which are direct connected to General Electric motors. These pumps are located in a pump house beside the cooling tower and at a level with the bottom of the

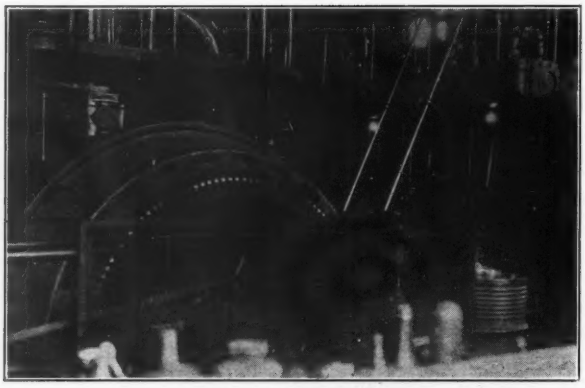


FIG. 2. COMPACTNESS IN THE ENGINE ROOM IS SHOWN BY THE SMALL SPACE OCCUPIED BY THE TWO DIESEL ENGINES

catch basin so that they are always "flooded." Operation of these units is by push button control. The water then flows by gravity to the engine jackets.

Diesel Engines Displace Steam Units

Originally this plant used steam motive power exclusively. Diesel engines have displaced all but one 17 by 21 in. Chuse non-releasing Corliss engine which is direct connected to a 160-kw. Western Electric Co. 3-phase, 60-cycle, 2300-v. alternator, operating at 0.8 p.f. and 200 r.p.m. Belted to this is a 10-kw. 125-v. direct-current, compound-wound, exciter running at 850 r.p.m.

Two Diesel units are installed; one, a 365-hp. Busch-Sulzer 4-cycle unit operating at 225 r.p.m. is direct connected to a 250-kw. General Electric 3-phase, 60-cycle alternator, 2300-v., 0.8 p.f. This is belted to a compound-wound, direct-current, 125-v. General Electric exciter, operating at 850 r.p.m. The second Diesel unit is a 550-hp. Nordberg 2-cycle engine direct connected to a 375-kw. General Electric, 3-phase, 60-cycle, 2300-v. alternator operating at 225 r.p.m. at 0.8 p.f. To this is belted a 12-kw., compound-wound, 125-v., direct-current General Electric exciter operating at 850 r.p.m.

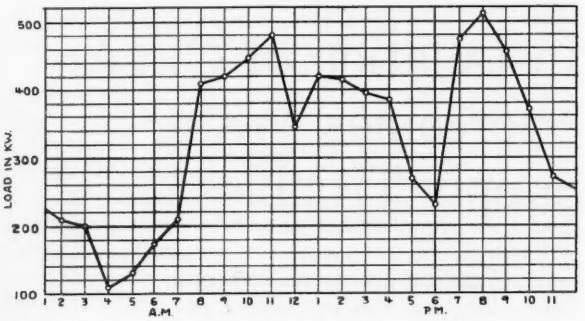


FIG. 3. LOAD CURVE FOR SEPT. 5, 1928, ILLUSTRATING TYPICAL FLUCTUATIONS

Load Carried Fluctuates Rapidly

Pumping of the city water supply, as well as distribution of electric light and power, is also a function of this plant. The minimum and peak total loads carried by the plant are 80-kw. and 525-kw. respectively. A typical load curve, showing the rapid changes that take place is shown at Fig. 3 and the corresponding daily station log, Fig. 4, indicates, as an example, how the different units were put into service on the day for which the chart was made.

CITY OF ROCHELLE, ILLINOIS
DAILY STATION LOG

Date Sept 5 1928

TIME	NORDBERG Generating Unit No. 1 Amperes A	B	C	KW.	BUSCH-SULZER-BROS. Generating Unit No. 2 Amperes A	B	C	KW.	CHUSE Generating Unit No. 3 Amperes A	B	C	KW.	EXCITATION Amperes Volts	No. 1	No. 2	No. 3	Totals	KW.
1:00	70	60	62	225									98	64				6.2
2:00	67	57	58	210									98	64				6.2
3:00	60	53	56	200									91	62				5.9
4:00	33	28	32	110									84	56				4.7
5:00	38	30	38	130									86	58				4.9
6:00	52	45	52	175									90	62				5.5
7:00	55	50	52	210									88	58				5.1
8:00	87	78	82	330					410	30	27	28	80	96	62		56	118	11.3
9:00	90	80	85	325					420	32	30	31	95	104	70		55	125	13.0
10:00	90	80	85	325					445	37	34	35	120	106	72		53	125	13.2
11:00	94	88	87	335					480	42	40	39	145	110	76		54	130	14.3
Noon 12:00	78	70	75	285					345	24	22	23	60	100	62		50	112	11.2
1:00	90	80	85	325					420	32	30	31	95	104	70		55	125	13.0
2:00	87	80	82	320					415	32	30	31	95	100	70		53	123	12.3
3:00	86	78	80	310					395	30	28	29	85	100	70		50	120	12.0
4:00	82	74	76	300					385	30	27	28	85	100	70		50	120	12.0
5:00	83	75	85	276										108	68				7.3
6:00	65	60	65	230										96	63				6.0
7:00	87	78	90	335					425	36	33	37	140	98	62		56	118	11.5
8:00	95	83	97	360					510	41	36	41	150	104	66		56	132	12.4
9:00	90	82	87	345					455	31	27	31	110	100	63		60	122	12.2
10:00	76	67	78	290					370	24	20	23	80	94	60		56	116	11.1
11:00	78	70	73	270										102	66				6.7
12:00	75	67	67	250										100	65				6.5

	Fuel-oil	K.W.H.-reading	Fuel-oil	K.W.H.-reading	Fuel-oil	K.W.H.-reading
Yesterday 12 night	199102	336400	474287	254600		215500
Today 8 a.m.	199279	337950				
	177	1550				
4 p.m.	199507	340250				216280
	228	2300				780
12 night	199747	342400				216725
	240	2150				495
Total	645	6000				1275
Gls. p. K.W.H.						

Total generated	K.W.-hr.		7275
Plant consumption	"		265
Total output	"		7010

	Coil	Fuel-oil	Lubricating oil	Grease	Boiler Compound	Water Rate
Kind						
Car No.						
Tons or Gallons						
Received						
Returned empty						
Returned						

REMARKS

WATT HOUR-METER READINGS, STREET LIGHT CIRCUITS

	No. 1 Today	No. 2 Today
	No. 1 Yesterday	No. 2 Yesterday
	K.W.H.	K.W.H.
CITY WATER PRESSURE PUMPS		
No. 2 pump today		87530
No. 2 pump yesterday		86900
K.W.H.		630
No. 3 pump today		
No. 3 pump yesterday		89280
K.W.H.		
No. 4 pump today		
No. 4 pump yesterday		
K.W.H.		
Total K.W.H.		
Lbs. coal used		
Av. feed water temp.		
Lbs. coal per K.W.H.		
Lbs. water per K.W.H.		
Factor of Evaporation		

CONSUMPTION OF

Engine oil Qts.	
Cylinder oil Qts.	
Rubilene oil Qts.	
Wilcoxene oil Qts.	
Grease Lbs.	
Re-cocene Qts.	
Gasolene Qts.	
Boiler compound Lbs.	

	No. 1 Today	No. 2 Today
	No. 1 Yesterday	
	K.W.H.	
AUXILIARY EQUIPMENT		
Reading today	9636	1800
" yesterday	9220	1710
K.W.H.	140	90
	230	
PLANT LIGHTS		
Reading today		
" yesterday		
K.W.H.	35	
CITY WATER PUMPED		
Reading today		
" yesterday		
Cubic Feet		
FEED WATER TO BOILERS		
Reading today		
" yesterday		
Lbs. water		

STREET LIGHTS

Circuit	on	off	Hours	Min
1	7:00 P.M.	4:30 A.M.	9	30
"	7:00 P.M.	4:30 A.M.	9	30
3				

STORAGE

Engine oil Qts.	
Cylinder oil Qts.	
Rubilene oil Qts.	
Wilcoxene oil Qts.	
Grease Lbs.	
Fuel oil Gals.	33+6718+4113
Boiler Compound Lbs.	

Engineers	from	to
W. BUNGE	8	4 P.M.
J. E. HALL	4	12
W. J. DETTMAN	12	8 A.M.

Changed over to boilers up.

FIG. 4. DAILY STATION LOG INDICATES GRAPHICALLY WHAT UNITS ARE IN SERVICE

Water is pumped for the city supply to a 220,000-gal. reservoir which is located 20 ft. from the power house, the top of the reservoir being at an elevation of 4 ft. above the power house floor. Two American Well Works centrifugal pumps, each having a capacity of 500 g.p.m. against 60 lb. pressure and one Worthington duplex pump having a capacity of 500 g.p.m. against the same head, supply the main pumping service. The water flows from the reservoir to the mains by direct pressure. Provision is also made whereby, on remote control from well No. 1, a reservoir of 83,000-g. capacity and a 300-g.p.m. Dean triplex motor-driven pressure pump may be put into service and pump direct into the mains. Installation of a new 1000-g.p.m. fire pump with automatic control and driven by a gasoline engine is contemplated. This will discharge direct into the mains.

Fuel oil, received on a railroad siding, is pumped by a small Worthington duplex pump from the tank car to three steel 11,500-gal. storage tanks located above the ground, as shown at the extreme right in the headpiece. When receiving fuel during the cold months, request is made to have it shipped in cars supplied with steam heating coils so as to permit attaching a steam line while unloading.

Daily supply tanks, located overhead at the engine as shown in Fig. 5, are supplied from the storage tanks by either a Viking rotary pump which is geared to a 1¼-hp. Allis-Chalmers motor or by an auxiliary hand pump, both of which are so piped that either pump may supply either engine. During this process, the oil passes through a strainer and for each engine a meter is connected in the line. The light oil used is gas oil of 32-36 deg. Baumé and the heavy oil is fuel oil at 26-30 deg. Baumé gravity.

Safety Device Avoids Overflowing

Each of the daily supply tanks, which have capacities of 500 gal., has two compartments, one small one for light oil to be used in starting and a larger one for the heavy oil. Both compartments of the tanks are provided with a device, to prevent overflowing, which until this device was installed, occurred several times. A float riding on the surface of the oil rises as the compartment is being filled, carrying a small cable up over a wheel and down on the outside in a slotted pipe shown on tank, Fig. 5. In the slotted pipe and at the end of the cable is a small counterweight to which a marker is attached. When this counterweight reaches the bottom an electrical contact is made which operates a type B2 Industrial Controller Corp. push button at the pump which in turn operates a controller and stops the pump.

Electric service is extended to rural sections surrounding the city. Lighting rates are as follows:

Farm lines, 14 cents per kw-hr.
City lines, 12 cents per kw-hr. for first 30 kw-hr.
10 cents per kw-hr. for over 30 kw-hr.
Stove rate is 5 cents per kw-hr.

Power rates, which are based upon a maximum demand on a 30 days basis, are:

11 cents per kw-hr. for first 30 hr. use maximum demand
6 cents per kw-hr. for second 30 hr. use maximum demand
4 cents per kw-hr. for over 60 hr. use maximum demand.

All of the foregoing are subject to a 1 cent reduction per kw-hr. if bill is paid within 10 days. There is also a quantity discount which is given on the 6 and 4 cents rates if, after deducting the prompt payment discount, the bill amounts to over $50.

So ably has this plant been operated by the engineers under the charge of Charles F. Lathrop, the superintendent, that, although certain forces brought much pressure to bear to bring about a sale of the plant to a utility company, the citizens of Rochelle turned this proposition down and by a vote of 3 to 1 endorsed the proposition to issue $35,000 bonds for additional equipment which includes a 900-hp. Diesel engine just purchased to replace the steam turbine. This engine is a 4-cycle, air injection Worthington Diesel, direct connected to a 625-kw. General Electric generator with direct-connected exciter and running at 225 r.p.m.

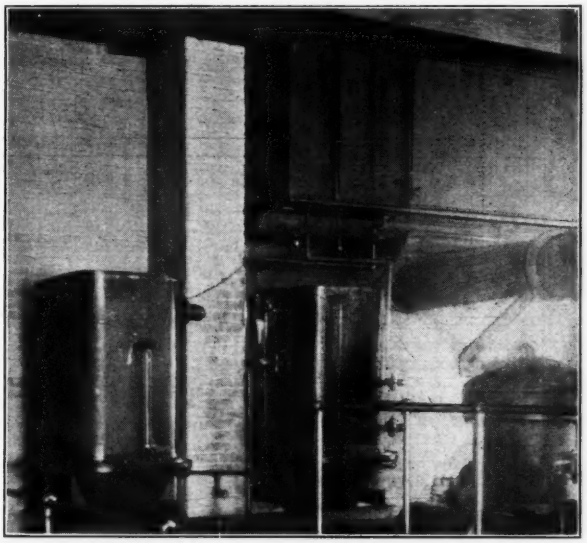


FIG. 5. DAILY SUPPLY OIL TANKS ARE EQUIPPED WITH SAFETY DEVICE TO PREVENT OVERFLOWING

Detailed operating expenses are enumerated as follows:

Operating disbursements	Year ending April 30 1925	1926	1927
75 per cent of salary of city clerk and assistant	$ 1265.63	$ 1518.75	$ 1518.75
Plant salaries	13,196.97	12,996.38	14,347.16
Maintenance and repairs	3393.41	1950.18	2089.29
Fuel	11,382.68	11,016.47	17,160.60
Oil, waste and packing	884.26	1398.00	1379.55
Supplies	603.63	351.96	427.94
Miscellaneous expenses, direct	1422.45	1795.12	1611.17
Miscellaneous expenses, joint	597.10	672.84	525.62
Total operating expense	$32,746.13	$31,699.70	$39,060.08
Revenues	$63,489.76	$65,772.87	$66,712.26
Excess receipts over operating expense	$30,743.63	$34,073.17	$27,652.18
Disbursements—operating	$32,746.13	$31,699.70	$39,060.08
Disbursements—capital	7047.89	34,312.24	11,495.33
Total disbursements	$39,794.02	$66,011.94	$50,555.41
Excess receipts over total disbursements	$23,695.74	$ 239.07	$16,156.85

Average annual net gain, $13,204.51.

Adapting Pulverized Fuel to Marine Boilers

COMPARISON OF SHIP PERFORMANCE USING FUEL OIL AND COAL AND DEVELOPMENT OF THE BLO-GUN ARE INTERESTING BYPRODUCTS OF SHIPPING BOARD TESTS

IN A PAPER presented before the Second International Conference on Bituminous Coal at Pittsburgh, C. J. Jefferson, head of the fuel conservation section of the U. S. Shipping Board Merchant Fleet Corp., and Commander J. J. Broshek, officer in charge of the fuel oil testing plant of the U. S. Navy at Philadelphia, reviewed the work carried on in adapting pulverized

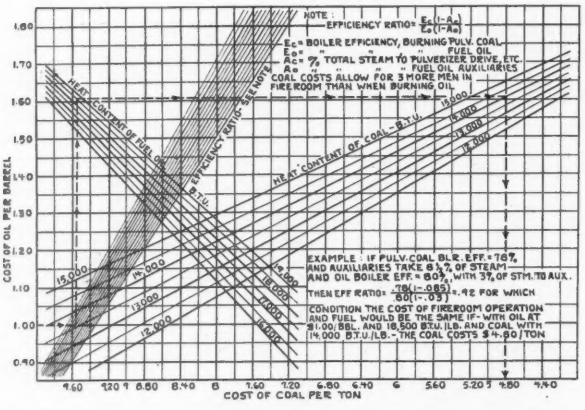

NOTE:
EFFICIENCY RATIO = Ec(1-Ac) / Eo(1-Ao)
Ec = BOILER EFFICIENCY, BURNING PULV. COAL
Eo = " " " FUEL OIL
Ac = % TOTAL STEAM TO PULVERIZER DRIVE, ETC.
Ao = " " " FUEL OIL AUXILIARIES
COAL COSTS ALLOW FOR 3 MORE MEN IN FIREROOM THAN WHEN BURNING OIL
HEAT CONTENT OF FUEL OIL - B.T.U.
EFFICIENCY RATIO
HEAT CONTENT OF COAL - B.T.U.
EXAMPLE: IF PULV. COAL BLR. EFF. = 78%
AND AUXILIARIES TAKE 6½% OF STEAM
AND OIL BOILER EFF. = 80%, WITH 3% OF STM. TO AUX.
THEN EFF RATIO = 78(1-.065) / 80(1-.03) = .92 FOR WHICH
CONDITION THE COST OF FIREROOM OPERATION
AND FUEL WOULD BE THE SAME IF WITH OIL AT
$1.00/BBL. AND 18,500 BTU/LB. AND COAL WITH
14,000 BTU/LB. - THE COAL COSTS $4.80/TON
COST OF OIL PER BARREL
COST OF COAL PER TON

FIG. 1. CHART USED FOR COMPARING THE ECONOMIC ADVANTAGE OF OIL AND COAL UNDER KNOWN CHARACTERISTICS

coal to marine boilers, particularly that leading up to the voyage of the S.S. Mercer.

At the time the S.S. Mercer was converted from fuel oil to pulverized coal firing, no changes were made in the power plant aside from the actual substitution of pulverized coal for fuel oil. Under these conditions, a reasonable check can be made by comparing her performance as a pulverized coal burner with the best performance obtained when using fuel oil. Such a comparison shows her best oil burning performance to be a voyage made exactly one year prior to her conversion. This voyage was made at 10-knot speed with 10.4 per cent slip, at a mean draft of 18 ft., using 270 lb. of fuel oil per mile. If adjustments be made for the 0.67-knot lower speed, the 3.53 per cent greater slip, and the 3 ft. 6 in. greater mean draft under which the first pulverized coal voyage was made, then the fuel per mile factor becomes 280 lb. per mi. for the oil burning performance.

CHART SHOWS THE ECONOMIC RELATION BETWEEN FUELS

Conversion factors on a B.t.u. basis for oil and coal are 1.3; therefore, the 280 lb. of oil per mile is equivalent to 364 lb. of coal, which, in turn, means that the thermal efficiency of the S. S. Mercer as a pulverized coal burner on her initial voyage was 96 per cent of that obtained on her best voyage made as an oil burner.

Relative economic merits of pulverized fuel, as compared to liquid fuel, are subject to so many variables that it is impossible to state, without knowing definitely all of the characteristics, such as unit cost and heat value, of each of the fuels under discussion for any particular application, just how much or how little would be gained by the substitution of the one fuel for the other.

As a means of making ready determination when the characteristics are known, a chart has been drawn up as shown in Fig. 1. On this chart are a series of straight lines giving the heat content of the coal, which are crossed by a series of straight lines giving the heat content of the oil. Both of these sets are crossed by another series of straight lines designated as the

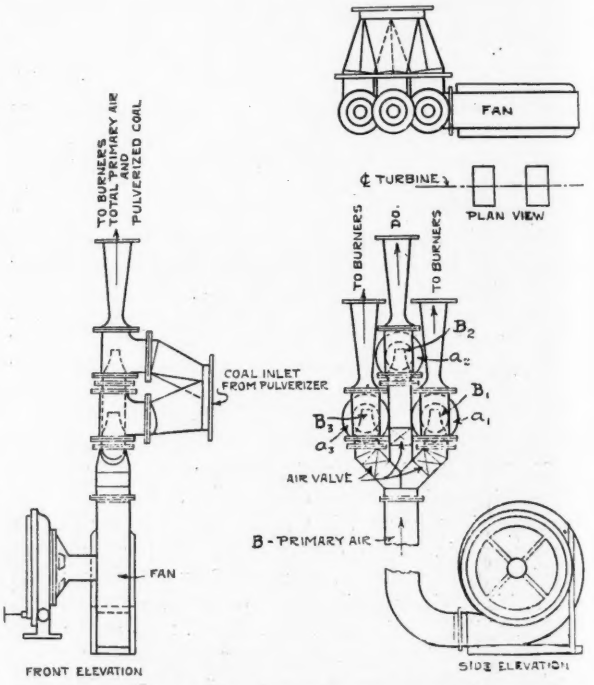


FIG. 2. FRONT AND SIDE ELEVATIONS OF THE BLO-GUN ARRANGED AS A PULVERIZER EXHAUSTER

efficiency ratio. The efficiency ratio is explained by the following equation:

Efficiency Ratio Equals: $E_c\ (1—A_c) \div E_o\ (1—A_o)$

where

E_c = Boiler efficiency, burning pulverized coal
E_o = Boiler efficiency, burning fuel oil
A_c = Percentage of total steam to pulverizer drive and accessories
A_o = Percentage of total steam to fuel oil auxiliaries

Coal costs allow for three more men in the fireroom than when burning oil.

To use the chart, you enter it from the ordinate side, at the price which you must pay per barrel for fuel oil, carry it over to the efficiency ratio line, which has been determined, and thence from the point of intersection go in a vertical direction to the heat value of the oil under consideration. From this intersection, carry over

in a horizontal direction to the heat value of the coal under consideration and drop down to the abscissa where you will obtain the maximum price that can be paid for a ton of that particular coal to equal the results that will be obtained from the particular type of oil purchased at the price originally assumed.

On the chart is drawn an example, using 18,500 B.t.u. oil purchased at $1.00, with an efficiency ratio of 92 per cent, compared with 14,000 B.t.u. coal, which shows that $4.80 is the maximum that can be paid for this coal to equal the cost obtained with this oil.

At the present state of development of pulverized fuel for marine purposes, we find that 92 per cent represents approximately the efficiency ratio that is being obtained. There is no reason, however, by adoption of efficient driving units for pulverization or the useful utilization of the exhaust steam from the pulverizing plant, why this efficiency ratio should not be brought up to 100 per cent, in which case the fuel cost would be raised to $5.20, or, in other words, the simple rule of comparison is that under present conditions pulverized fuel operating costs are equal to those of fuel oil when you can purchase 4.8 bbl. of 18,500 B.t.u. oil for the price of one ton of 14,000 B.t.u. coal but that it is entirely reasonable that this ratio be increased from 4.8 to 5.2.

The initial voyage of the S. S. "Mercer" was made with 14,000 B.t.u. coal costing $5.05 per ton. Applying this value to Fig. 1, it will be noted that it would require $1.01 per bbl. or less oil price for 18,500 B.t.u. oil to equal or better the fireroom operating cost of this voyage.

Blo-Gun Developed to Get Away from Exhauster Erosion

Early in the operation of the S. S. Mercer, it became apparent that serious consideration must be given to the erosion by pulverized fuel on the primary air fan as the effect of fan blade erosion extends beyond the fan itself, as the erosion is not uniform and an unbalanced high speed fan quickly sets up vibrations which may prove disastrous to the fan drive.

There are several methods of attacking the problem, as, for example:

The use of forced draft instead of induced draft for air sweeping mill. This method is now employed by several pulverizer manufacturers and is fairly satisfactory; however, it has a tendency to create turbulence in the mill which militates somewhat against classification of superfines by air current.

Use of special materials for manufacture of fan blades: Considerable experimental work has been conducted along this line, which has resulted in varying success under different conditions. Up to date, ordinary soft iron has, however, given the best universal service.

Use of comparatively cheap and easily renewed rotor: A number of shore plants have adopted this compromise method but it cannot be accepted as satisfactory, since it interferes with continuous operation such as must be maintained by the seagoing installation.

A fourth method is to apply the ejector principle, which has been attempted at the Test Plant by the use of the so-called Blo-Gun. In attacking the problem of fan erosion, the engineers of the B. F. Sturtevant Co. were called into consultation and the Blo-Gun, as finally evolved, is the result of their coöperative effort.

The original idea was to have a single ejector nozzle operating on outlet of mill and discharging to a distributor head. It was decided, however, to attempt to work out not only fan erosion but also distribution with the same device. The Blo-Gun as finally built is shown by Fig. 2, a line drawing of the set-up.

The principle of the device is to create a partial vacuum by means of a high velocity air current discharging from a nozzle across an enlarged chamber into a venturi throat. The partial vacuum sets up an air current which sweeps through the pulverizer, picking up the finely pulverized fuel and carrying it into the mixing chamber, where it joins with the stream of injection air and forms the total primary air and coal mixture going to the burner.

Injection air or fan discharge is the carrier air which is known as the b air. The induced air from the mill

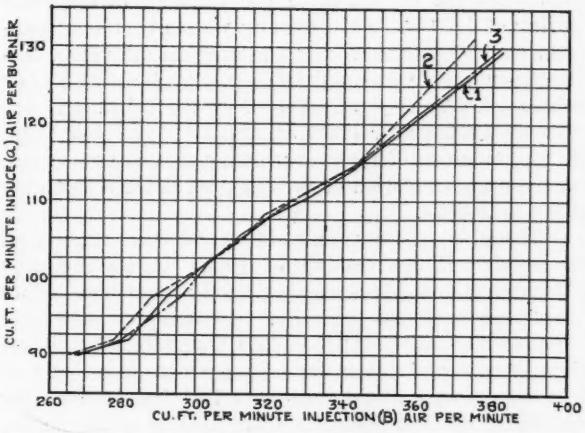


FIG. 3. CHART SHOWING THE PERFORMANCE OF THE BLO-GUN

which sweeps out the pulverized fuel is known as the a air. The combination of a and b air is the primary air of combustion. The device must be set up close to mill discharge as long leads will either create so great a friction that the b air cannot create sufficient vacuum to maintain an induced air circuit or else in order to overcome friction the pipe areas will be so large that sufficient velocity will not be maintained to keep the coal in suspension.

Furthermore, the b air, which is of approximately the same proportion to the total primary air as is the carrier air usually introduced between mill and primary air fan, precludes the admission of additional carrier air such as would be required if connections be removed from close proximity to mill discharge, as additional air would produce too lean a mixture for satisfactory combustion.

Service tests with Blo-Gun direct-connected to the mill have not yet been conducted but quantitative values of a and b air have been determined by measuring the flow from fan and the induced air by means of orifices. The results of these trials were shown on Fig. 3, a series of three graphs giving the a air quantities for each of the three mill connections plotted against the b quantities. During these trials, no air valves were installed in b connections. The need of such valves for proper distribution is shown by variation at the higher rates.

Edison was Disguised

How I Discovered It but Didn't Get Onto His Bandwagon. By Hubert E. Collins

WANTED. Steam Engineer to operate a Corliss engine in our ore concentration plant. Must be able to read indicator diagrams and analyze the same. Good pay to the right man. Apply to Superintendent at works. Take New York Susquehanna & Western Railroad to Ogdensburg, N. J., and thence to Edison, or proceed by D. L. & W. to Dover and there take Central Railroad of New Jersey direct to Edison. Applicant's fare paid one way. New Jersey & Pennsylvania Concentrating Works, Edison, N. J.

AN AD OF THIS import in the World want columns attracted my attention one morning in the early spring of 1899 while the big city was in complete darkness at 5:00 a. m. I was an independent young mechanic-engineer who could do equally well as engineer or machinist. Temporarily out of work, I had left my wife at the flat near 116th St. and 9th Ave., New York, to purchase one of the first morning papers put on sale at the up-town station of the 9th Ave. L, for a look over the possibilities.

The ad caught my fancy, because I was then termed an expert at the reading of steam engine indicator diagrams and the idea of proving my knowledge before strangers appealed strongly. I was not sure that Thomas Edison was at the place designated, but I had been reading of his interest in ore concentration and the idea that I might meet him had influence on my decision. It took me but a short time to decide on the venture. I told my wife of the prospect, then took the L and ferry that carried me to the station where I boarded the train for Ogdensburg, N. J.

Why I chose that route I can not tell and I did not much care how I was to reach the obscure town of Edison after I had arrived at Ogdensburg. While the train bore me onward across New Jersey, I tried to visualize what was ahead and vaguely wondered if I would meet Thomas A. Edison. I thought back 4 or 5 yr. when I, a young machinist, had helped erect a Williams vertical engine in the Gwinnett St. Brooklyn-Edison Station. This engine was of radical design, with a newly designed Edison generator direct-connected. The positive pole armature was at one end of the engine shaft while the negative was at the other extreme. The two were faced off into commutators and made an attractive picture with the plethora of copper then used in generators. Opening of that station had been graced by the presence of Mr. Edison with other dignitaries and the occasion had made a great impression on me.

The picture was banished when the train slowed down for Ogdensburg. When I alighted, there seemed no means of conveyance at hand but the station master told me I could reach Edison by following a road that he pointed out and walking about three miles up into the hills. Spring thaws had loosened the dirt so that the going was through mud ankle deep, below a layer of snow and slush. Working my way along the road, I finally came to a gap in the hills and I looked down into a basin where a few buildings gave me the impression of a western mining settlement.

In the center of the basin was a large building with a boiler smoke stack and conveyors serving large machinery hidden from sight. Other smaller buildings seemed to house engineering offices. On one side of the depression in the hills and well above the large building in the center were several partially completed dwelling houses. Wherever a roof showed clear of snow and slush, there appeared a heavy coating of ore dust. In fact, everything thereabout was covered, including the few bare trees. Underfoot was a mass of Jersey mud. It filled the road and covered the hill sides.

Down the incline I splashed, through mire to the main building. As I approached, it seemed that everything was standing idle but, as I neared the door leading into the main building, a rather stocky man seemed headed for the same opening. I looked him over and noted pink ruddy cheeks with light colored grey hair showing from beneath the brim of an old slouch hat, while five or six days' growth of grey beard showed on his face. He wore rough top boots and an old suit of clothes with pant legs pulled to boot tops but not tucked in. He was covered with ore dust and heavy layers of mud had splashed over him from head to foot. I asked him where I would find the superintendent. He did not answer at once but motioned me to follow him.

Entering the main building, we passed some ore crushers to a spot where were a small desk and chair, also covered with a deep layer of the ore dust. The man sat down in the chair and turned inquiring eyes toward me. When I again indicated that I would like to see the superintendent, he said, "I am the superintendent."

At once, I told my mission. He told me that they needed an engineer and restated that the successful man must read some indicator diagrams to qualify. In fact, that was the first requirement. I asserted my ability to comply. He then asked me several more questions as to my general qualifications, then, seeming satisfied, arose and asked me to follow him.

As we walked side by side through the main building, I opened a conversation to satisfy my own curiosity. Having looked at the man, I seemed dimly to recognize him. Not being sure, I asked, "Are you any relation to Thomas A. Edison?" "He is a cousin of mine," said he. "You look like him," said I.

By this time, we had reached a drafting room in another building and the superintendent, introducing me to his head draftsman, a Mr. Herter, I believe, left me with him, after saying he would see me again. Mr. Herter lost no time in producing several engine indicator diagrams for my inspection and interpretation. They were puzzlers indeed. I had never seen the like. But I laid them out on the board and proceeded to trace the action shown on one. I identified steam line, cutoff, expansion and point of release, all out of place. Finally

I said, "This diagram shows a badly twisted valve stem."

Mr. Herter smiled, said that I had diagnosed correctly the trouble shown on the diagram and told me that the mill was then shut down because one of the valve stems on the Corliss engine had twisted off and they were repairing it at the time. The diagram had been taken just before the steam valve stem had given away. He then said that the superintendent would be glad to engage me as engineer when he heard that I read the diagram aright and that I could do the same for any others. Speaking of the superintendent brought my mind back to him and my suspicions. I then asked Mr. Herter, "Who is the man I have been talking with?" "That is Thomas A. Edison," said he.

As I told Mr. Herter what had transpired just before I came to him, he laughed when he heard "He is a cousin of mine." Telling Mr. Herter I would hunt the superintendent up myself, I went back and found Mr. Edison in the engine room where he was looking at the broken valve stem while awaiting my arrival.

It seemed to tickle Edison himself that the laugh was on me over my identification of him, for he grinned and let out a chuckle before getting down to business. After hearing what I had done and the remark of Mr. Herter, Mr. Edison, without waiting to verify my story, proceeded to talk business, with my engagement in view.

We looked the damaged valve stem over and he asked me my opinion of the cause of the trouble. He added that the valve stems had broken several times and shut the mill down each time. I ventured the opinion that the stems had been allowed to run dry, they had seized close to the T head and slowly twisted off. He said that seemed probable to him. We also spoke of the quality of bronze in the valve stem as a possible question but I still think the valve stem was not properly lubricated.

Soon we were talking terms and I was offered $3 a day to work as engineer, which was good pay at the time and I was inclined to take the position. Mr. Edison told me that he expected some houses to be completed within a few weeks and I could then bring my wife there to live while I worked. I had left the house that morning expecting to return in the evening and to avoid worry on the part of my wife I would need to go back to the city again each night. Those three miles of mud rose before my mind, also the time I would have to leave home in the morning and when I would get back at night. It didn't look so good, even for a few weeks. Finally I decided not to take the job so as to be in line for work where I could get home each evening. I told Mr. Edison my decision before leaving and he paid me the fare one way, bade me good bye with a hearty laugh and cautioned me not to be taken in by that "cousin of his." "Well," I said, "that cousin did look like Mr. Edison."

AS REPORTED to the Department of Commerce by 81 manufacturers, new orders for 1343 steel boilers were placed in December, 1928, as compared with 1660 boilers in November and 1459 in December, 1927. This total of 1343 boilers had a total heating surface of 1,308,125 sq. ft.

Natural Gas for El Paso Power

SUPPLY FROM NEW MEXICO FIELD TO DISPLACE COAL AND OIL. BY M. W. BAKER

GRADUALLY developed industries, with large demands for power, have adopted coal as the fuel most used, with oil gradually creeping into its place as a power generating agent. Since the supply of fuel oil is said to be limited, the opening of the Lea County, New Mexico, natural gas field, and subsequent granting of a franchise to the El Paso Gas Utilities Corp. and the Texas Cities Gas Co. for the distribution of natural gas, has been welcomed as a happy solution of the problem of more fuel.

Coincident with the building of the pipeline—a distance of more than 200 mi. across the desert, the Delaware Mts. and the Pecos River, the El Paso Electric Co. is preparing to expend somewhere in the neighborhood of $300,000 to change its furnaces from coal to natural gas.

As uninterrupted service is essential, this change will have to be made gradually.

Nine large boilers, eight of 600 hp., the ninth 1155 hp., have the latest type of stoker furnaces and, to change over to gas, will mean tearing out the entire fronts, relining the walls with fire brick, laying an additional firebrick floor over the present floor and replacing the front with a steel-beam-reinforced, sheet-iron front, across which the gas pipes will be carried. Oil burners will be also installed so that, in case of emergency which might cause a stoppage in the gas supply, the oil could be turned on with a loss of not over two minutes.

This plant furnishes all the light and power used in El Paso and nearby towns, as well as operating the street railway system and, to care for the peak load between five and six o'clock in the afternoon, requires five of the 600-hp. boilers and the large 1155-hp. boiler.

That the financial saving which will be effected by the installation of natural gas will be considerable is indicated by the expenditure of $300,000 to make the change, which will be started within a few weeks.

Other plants planning to install natural gas are the Southwestern Portland Cement Co., which has a capacity of 3300 bbl. a day, and the El Paso Smelter, one of the Guggenheim properties. As practically 85 per cent of the power for the cement plant is generated by waste heat from the kilns, the gas used in firing the kilns will also generate power and, if it is decided to complete the installation in all kilns, the auxiliary boilers will also be equipped with gas burners. Oil has been used for 15 yr. at the smelter.

Here, too, the gases pass from the big reverberatory furnaces through the boiler flues above them to generate the power for the huge plant which sprawls all over the tops of half a dozen hills. If one of the furnaces is shut down, auxiliary power is required for about 25 per cent of the plant and natural gas will be installed under these auxiliary boilers also.

Other industries, brick plants, foundries and machine shops are preparing to use natural gas, so that practically every large industry in El Paso will be equipped and ready to have the gas turned into its plant when the pipeline shall have been completed and connected with the city mains about May 1.

Unit Heater Tests Show High Heat Transfer

TESTS AT BROWN UNIVERSITY SHOW THAT HEATER OCCUPYING 5 CU. FT. OF SPACE CAN DISSIPATE OVER 350,000 B.T.U. PER HR. WITH CONVENTIONAL FAN EQUIPMENT. BY HERBERT CHASE

EFFECTIVENESS of industrial heating equipment is demonstrated by tests recently completed at Brown University under the supervision of James A. Hall and P. N. Kistler, professors of mechanical engineering at that institution. These tests show, for example, that a unit heater, known as the Grinnell Thermolier, Fig. 1, and occupying a space of less than 5 cu. ft., motor and fan included, will transfer from 100,000 to 360,000 B.t.u. per hr., depending upon incoming air temperature, steam pressure and speed of fan. The Thermolier is built up somewhat after the fashion of the fin-and-tube automobile radiator but is much heavier, more rugged, and is designed for higher pressure. Also, instead of using through tubes from top to bottom headers, it employs tubes bent into a U-shape, Fig. 2 with ends expanded (without solder) into a cast-iron header plate, Fig. 3, at one side of the unit. Each tube is pitched ¼ in. in its length (about 2 ft.) in the direction of steam flow to insure proper drainage.

These tubes are of seamless copper, ⅜ in. diameter. They are banked two U's deep, or four legs staggered, from front to back. There are 47 complete U's in the core, therefore the tubes cross the core a total of 94 times. Since the unit is about 2 ft. square (3.5 sq. ft. frontal area) the total length of tubing approximates 190 linear feet.

CONSTRUCTION OF FINNED TUBES

Upon each leg of each tube there are pressed 132 stamped and slightly corrugated brass fins ⅞ in. square, Fig. 4. When fins are in place, the fin and tube assembly is dipped into a bath of solder, not to increase strength but to insure a permanent metal bond for perfect heat conduction from tube to fin.

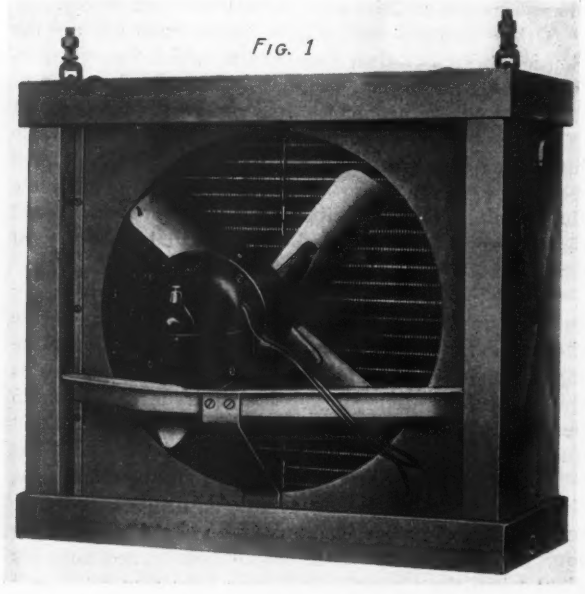


FIG. 1. UNIT HEATER TESTED AT BROWN UNIVERSITY

With these fins, there is a total of approximately 155 sq. ft. of radiating surface over all of which a forced draft of air from the fan passes. Virtually all of this surface is in an approximately vertical plane, hence the chance of dust collection (with consequent decrease in efficiency) is minimized.

At the back of the unit is mounted an electric motor carrying an 18¾-in. fan with bronze hub and aluminum blades. This fan runs within a closely fitting shroud (Fig. 1) which ensures air circulation through the entire area of the core. The unit tested is made in two models numbered 600 and 800 respectively, the only difference being in the speed and power of the motor. The former runs at 850 and the latter at 1150 r.p.m., delivering respectively 1700 and 2500 cu. ft. of air per minute. These units are designed for steam pressures up to 125 lb. although the copper tubing has a bursting strength exceeding 9000 lb. The cast-iron header at one side of the unit is divided by a vertical partition. The chamber A, Fig. 5, toward the fan is tapped for a 1½-in. steam supply at the top. The upper legs of all but the two lowest U-tubes open into this chamber, hence are fed by live steam which flows into each tube. During its passage, the steam gives up its heat to the walls of the tubes and is condensed, the condensate flowing by gravity into the second chamber B, thence into chamber C and the upper legs of the two lowest U-tubes. The latter, being cooled by the air blast from the fan, cool the condensate and form an efficient internal cooling-leg, hence no external cooling-leg is required.

HOW THE TESTS WERE CONDUCTED

During the capacity tests, the Thermolier was set up near an open window with a short wooden inlet duct so arranged that either cool air from outdoors, warmer air from the test room or a mixture of the two could be admitted. This gave a means of varying and controlling the air inlet temperature.

For convenience in the test, the copper louvers regularly furnished with and attached to the unit for directing the air flow as desired were removed and a 3-ft. length of metal outlet duct put in place to facilitate measuring the velocity, quantity and mean temperature of the air issuing from the unit.

In place of several thermometers, the temperature of outlet air was measured electrically by determining the change in resistance of a fine copper wire properly calibrated and stretched across the outlet duct. This was done because it was found that considerable differences in temperature existed at various points in the cross section of the air stream. With the resistance wire, it proved easy to secure quickly a correct mean value.

Steam at the various pressures desired was available in the laboratory. To ensure that it entered the Thermolier dry, it was passed through a steam separator immediately before entering the unit under test. The temperature of the condensate was measured at the

point at which it left the Thermolier and its quantity was learned by weighing the amount discharged during 3-min. intervals. These measurements made it possible to determine the quantity of heat given up by the steam (which, of course, is equal to that absorbed by the air) and yielded the capacity figures desired.

A regular ¾-in. thermostatic trap was installed at the outlet and a uniform flow obtained with the temperature of the condensate only a few degrees below that of the steam. All tests were continued long enough to make certain that operating conditions were constant.

Tests were made at fan speeds of 850 and 1150 r.p.m., the standard fan speeds in which the Models 600 and 800 Thermoliers are furnished, and at eight steam pressures: 1, 5, 10, 25, 50, 75, 100 and 125 lb. gage, respectively. In most cases the capacities were determined also for a considerable range of incoming air temperature.

What the Tests Show

One of the purposes of the test was to determine the fan capacity constants and the coefficients of heat transfer from core to air; for with these at hand, it is possible to calculate heat transfer capacity. Conversely, knowing the capacity of a given unit, which the test data provide, the constants and coefficients can be calculated.

For a given fan speed, the weight of air flowing per min. should vary directly as the absolute pressure and inversely as the square root of the absolute temperature. Taking a barometric pressure of 14.7 lb. per sq. in. and an air temperature of 40 deg. F. as a basis, the weight of air discharged per hour, W, is given by the following equation:

$$W = C \frac{P}{14.7} \sqrt{\frac{500}{460 + t_1}} \qquad (1)$$

where P = abs. press. of entering air, lb. per sq. in.
t_1 = temp. of entering air in deg. F.
C = lb. of air discharged per hr. under standard barometric pressure and with t_1 = 40 deg. F.

Substitution of test data in this equation (1) gave the following average values for C:

Fan speed 1150 r.p.m., C = 9234
Fan speed 850 r.p.m., C = 6702

For a given air speed, the heat transfer should be proportional to the logarithmic mean temperature difference between steam and air, or

$$H = K \left[(t_2 - t_1) \div \log_e \frac{t_s - t_1}{t_s - t_2} \right] \qquad (2)$$

where H = heat transferred per hour, B.t.u.
t_s = temperature of steam
t_1 = temperature of entering air
t_2 = temperature of leaving air
K = coefficient of heat transfer

Values of K, as determined from test data, proved to be nearly constant for a given fan speed, the average results being as follows:

Fan speed 1150 r.p.m., K = 1808
Fan speed 850 r.p.m., K = 1532

Now, since the heat absorbed by the air is equal to the weight passing in unit time, times its specific heat at constant pressure (S_p 0.241) times its rise in temperature, we can write the equation:

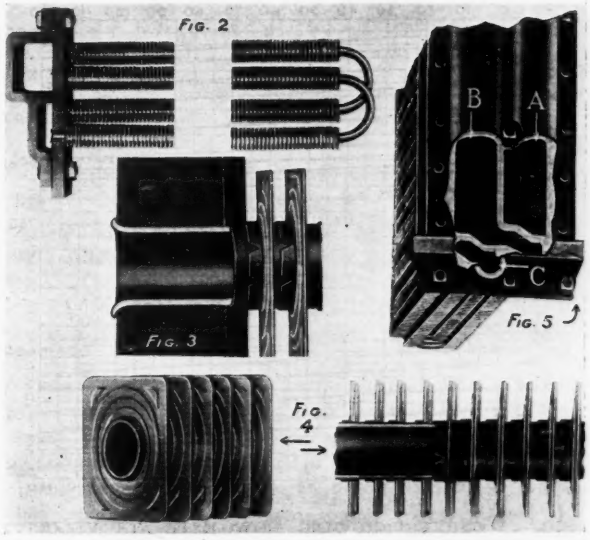
$$H = WS_p (t_2 - t_1) \qquad (3)$$

and combining equations (2) and (3) we get

$$\frac{K}{WS_p} = \log_e \frac{t_s - t_1}{t_s - t_2} \qquad (4)$$

Knowing the values of constant C and coefficient K, the weight of air discharged by the heater is obtained by equation (1) for any given temperature and pressure of entering air.

With the steam pressure and temperature known and also the temperature of entering air, the exit temperature of the air is determined by equation (4), while the heat transfer then is determined by equation (3).



FIGS. 2-5. DETAILS OF HEATER UNDER TEST. FIG. 2. U-SHAPED TUBES. FIG. 3. METHOD OF EXPANDING TUBE END INTO CAST-IRON HEADER PLATE. FIG. 4. SHOWING HOW FINS ARE ATTACHED TO TUBE. FIG. 5. ARRANGEMENT OF CHAMBERS FOR ADMITTING STEAM TO TUBES

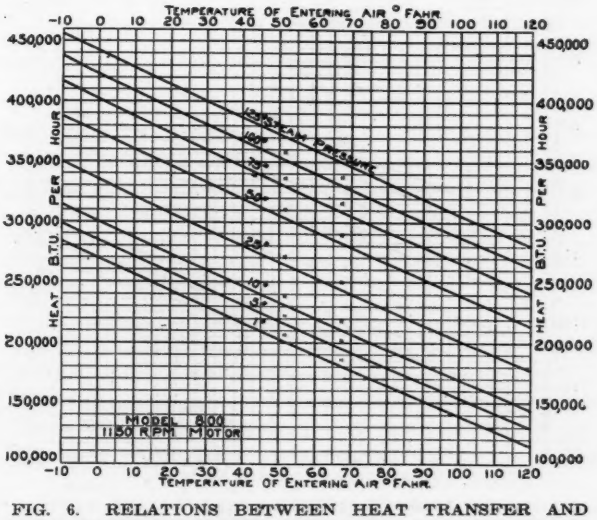


FIG. 6. RELATIONS BETWEEN HEAT TRANSFER AND INCOMING AIR TEMPERATURE AT A GIVEN AIR SPEED

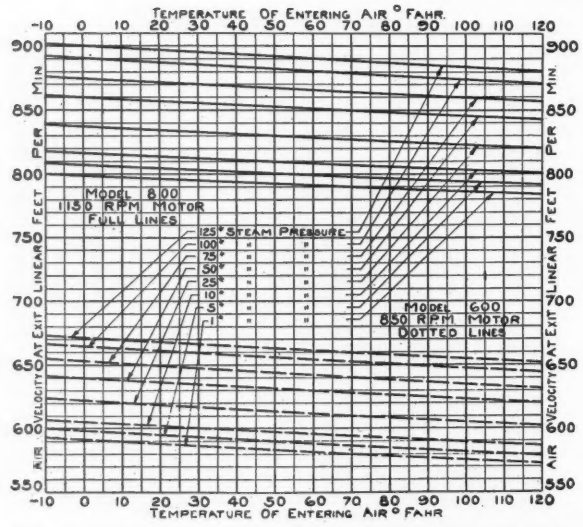


FIG. 7. CURVES SHOWING HOW EXIT AIR VELOCITY INCREASES WITH INCREASE IN STEAM PRESSURE

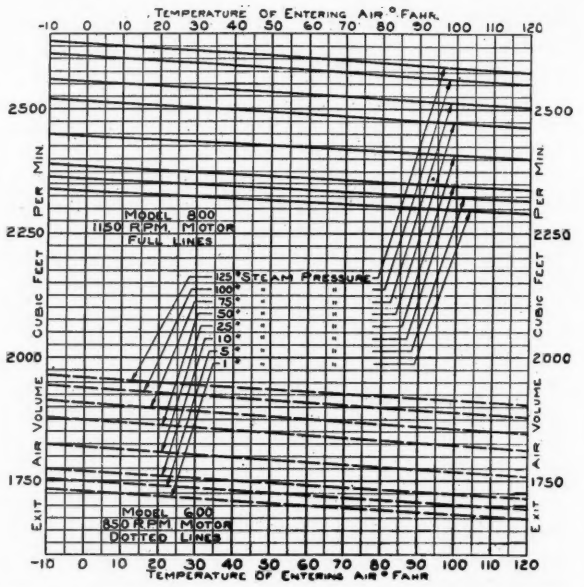


FIG. 9. RELATIONS BETWEEN ENTERING AIR TEMPERATURE, AIR VOLUME, FAN SPEED AND STEAM PRESSURE

By use of these equations and constants, the data for the accompanying curves have been calculated. Points determined experimentally agree within three per cent with the calculated results through practically the entire range.

Analysis of Test Results

Inspection of the curves indicates the following among other facts:

1. The heat transfer for any given air speed (Fig. 6) falls off in direct proportion to the increase in incoming air temperature.

2. The heat output does not increase in direct proportion to the increase in steam pressure but in a lesser ratio. Thus the increase in output (for an incoming air temperature of 40 deg. F. and a fan speed of 1150 r.p.m.) is from 232,000 B.t.u. per hour at 5 lb. steam pressure to 281,000 B.t.u. at 25 lb., or 17.4 per cent, while a pressure increase from 100 to 120 lb. increases the output from 369,000 to 384,000 B.t.u. per hr. or an increase of only 4.1 per cent.

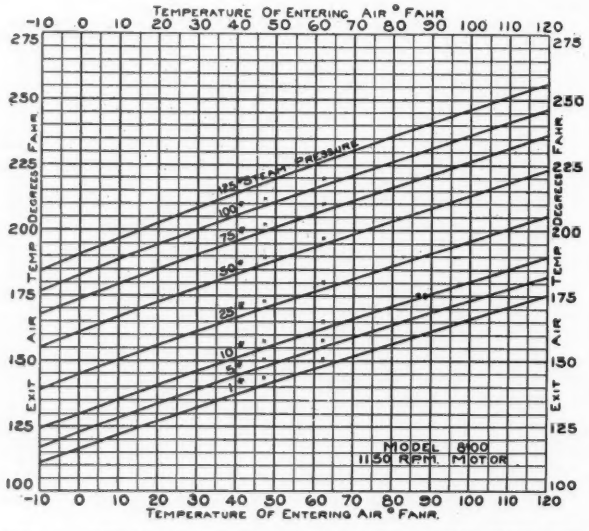


FIG. 8. RELATIONS BETWEEN ENTERING AND EXIT AIR TEMPERATURES AT A GIVEN FAN SPEED

3. Air velocity at exit from heater is not constant for a given fan speed, (Fig. 7) but increases as the steam pressure (and consequent temperature of the heating coils) is increased. This increase approximates 12 per cent as between steam pressures at 1 lb. and 100 lb., at a fan speed of 1150 r.p.m.

4. Exit air temperatures at constant fan speed of 1150 r.p.m. vary from 112 deg. F. with incoming air at 10 deg. F. and 1 lb. steam pressure to 247 deg. F. at an incoming air temp. of 120 deg. F. and a steam pressure of 100 lb. (Fig. 8).

5. At a constant fan speed of 1150 r.p.m. and an incoming air temperature of 60 deg. F., the volume of air leaving the unit varies from about 2280 cu. ft. per min. to about 2535 cu. ft. a min. as the steam pressure is raised from 1 lb. to 100 lb. (Fig. 9), the increase in volume being due, of course, to the greater absorption of heat at the higher steam pressures (and temperatures). In this case, the absorption of heat under the two conditions just mentioned amounts respectively to 191,000 and 342,000 B.t.u. per hr., while the exit temperature increases from 147 to 217 deg. F.

In commercial refrigeration plants, ammonia is the gas commonly used. The ammonia gas is compressed and then cooled in the condenser until it liquefies. During the process of compression and liquefaction, heat is given up by the gas and is removed by the cooling water. The liquid ammonia is expanded through an expansion valve, and because of the lower pressure it vaporizes absorbing heat from the surrounding materials, either air in cold storage room or brine in a tank. Neglecting radiation losses, the amount of heat absorbed by the vaporizing ammonia liquid is equal to the heat which must be carried away by the cooling water.

High-Pressure Boiler for Safety Valve Testing

ASHTON VALVE CO. INSTALLS 650-LB., 168-HP. BOILER FOR TESTING SAFETY VALVES UNDER ACTUAL SERVICE CONDITIONS. UNIT IS OIL FIRED, AN EXCELLENT EXAMPLE OF INDUSTRIAL PLANT DESIGN

TO MAKE IT POSSIBLE to carry on actual safety valve tests at pressures up to and including 650 lb. per sq. in. in its own shops, the Ashton Valve Co. of Boston recently installed a 1680-sq. ft., 650-lb., type S, oil-fired, cross-drum Heine boiler.

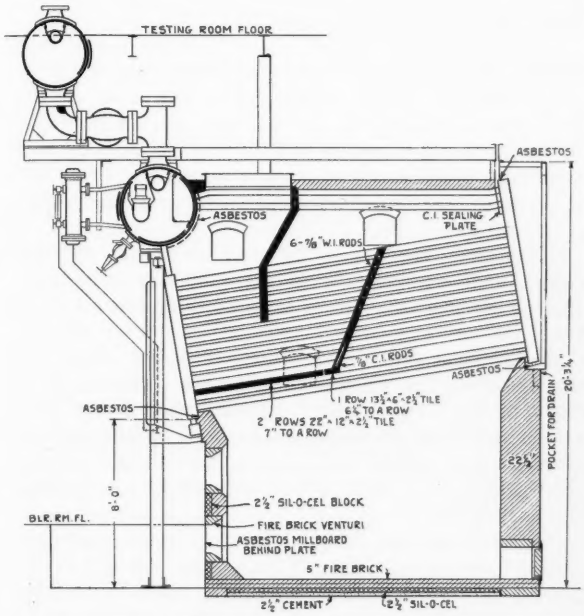


FIG. 1. CROSS SECTION OF THE BOILER AND SETTING

Since the new boiler is used for testing purpose, a large heating surface was not necessary, the prime requisite being the production of large volumes of steam under close control for comparatively short periods in order to check accurately the relieving capacity and blow-down pressures of safety valves.

As can be seen from the cross section, Fig. 1, the boiler, of vertical baffle three-pass construction, is oil fired by two Todd forced draft oil burners, is designed for 300 per cent rating and, although the installation is especially designed to meet the demands of safety valve testing, the furnace and boiler construction itself is an excellent example of small high-pressure, industrial plant design.

In addition to the steam demands, it was necessary to provide a number of points to which safety valves could be attached for testing purposes. For this reason, as well as to provide steadiness of steam flow and close pressure regulation an additional 36-in. steam drum is provided as shown in Fig. 1. This auxiliary or storage drum is attached to the steam nozzle of the main 42-in. boiler drum by means of a tee connection and a valve.

This is a flexible arrangement which permits obtaining any desired pressure in the testing drum within the allowable boiler pressure and testing two valves at the same time if for the same pressure. The top of the auxiliary drum is slightly higher than the testing room floor so that the safety valves to be tested are at a convenient height as shown in Fig. 2.

Schutte & Koerting gate valves controlled by large hand wheels are enclosed in boxes packed with mineral wool. The safety valves to be tested are placed on these large gate valves. The two small valves at the side of the gate valves control the bypass and blowoff respectively.

Steam to the testing drum is controlled by the wheel on vertical shaft shown between the two test valves, steam pressure in this test drum being indicated by the two gages on the wall at the left; one is used for high and one for low pressures. Other wheels operated either from the test room or boiler room, control the

FIG. 2. SAFETY VALVES BEING TESTED. THE TOP OF THE AUXILIARY DRUM COMES JUST ABOVE THE TEST FLOOR LEVEL

larger valve connecting the two drums when capacity tests are run, or in case of an emergency. Chain and air hoists are conveniently located for handling the valves to be tested.

Both drums are butt riveted and the boiler drum has two additional inside straps at the points where the circulating nipples enter. Tubes, seamless steel, 3½ in. in diameter and 15 ft. 10 in. long, enter sectional rectangular headers with $\frac{11}{16}$-in. walls. Both drums and boiler are carried on steel framework supported on concrete caissons extending down to gravel 22 ft. below normal ground level.

Injectors, duplex 4½ by 2¾ by 4-in. fuel oil pump and heater set are installed in a small steel walled room at the right of the boiler, only the injectors being visible in Fig. 3. A Worthington duplex 10 by 3½ by 10-in. boiler feed pump installed in the pump room adjacent to the boiler room is used for normal operation.

Figure 3 is a front view of the boiler showing the Todd burners, motor-driven forced draft fan and

starter, Yarway blowoff valves, Edward feed and check valves and Schutte & Koerting injectors.

Normally, the new boiler supplies steam at 125 lb. pressure for operation of the engines and pumps through a Mason reducing valve. When making capacity tests on valves, however, or when testing at pressures over 450 lb., the hand-fired boilers are started up and the test boiler is cut off the power line. The original Heine hand-

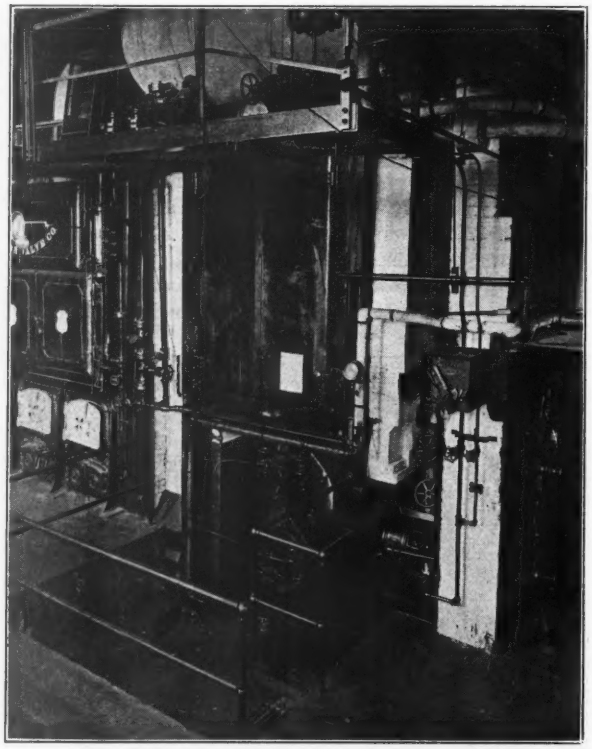


FIG. 3. FRONT VIEW OF THE BOILER SHOWING THE OIL BURNER AND SOME OF THE AUXILIARIES

fired 150-lb. power and 400-lb. testing boilers, shown at the left, Fig. 3, are still used for their original purposes when the new boiler is shut down or used for special work as described.

Steam Fuel from a Resin Mine

TO CREATE a coal mine Dame Nature took thousands or millions or billions of years. What are a few ciphers among friends? Anyway, she took her time. Woman can improve on nature in jig time. It takes nature several or more years to develop a flapper but the flapper can improve on nature in anywhere from ¼ to 1½ hr., depending on how soon she wants to start to go places and do things.

Well, man can also discount nature—sometimes. And one instance is a fuel mine, now in active production, which was started only a dozen years ago.

In a war-baby ship building plant, now reduced to light drop-forging activities and, with acres of silent buildings witnessing how we made savings for democracy, power and steam are still needed for the hammers and oil-burning forges. But the location makes coal or oil expensive as a steam-making fuel and fuel cost was a large item for power.

Nearby wood-working plants were burdened with an excess of wood waste for, in this locality, heat is not an essential at any season and such plants require little power. This wood waste—for the hauling—was the fuel solution for a time but, "came the dawn" when others besides the resourceful engineer in this plant awoke to wood-waste fuel value so that demand outran supply and the cost of wood-waste began to rise. What to do?

Let's ramble around and take a look. Over there on the back of the sundry acres of war-baby realm was a useless low spot, next to a turpentine refinery. After the refining, a residue remained which was a mean, sticky mess when hot but would flow. Cold, it is the consistency of lignite only not so brittle.

"Can we dump this mess on your low spot?" was the request of the refinery people, several years ago.

"Certainly. Dump all you like. Fill it all up and we'll raise town lots on it," was the complaisant reply.

And so they dumped and dumped—tons and tons and more tons—many more—of resinous residue and the mosquitoes were evicted and everybody was happy, except the mosquitoes.

There was the mine. "Pitch pine burns, why not resin?" So reasoned the engineer. "Fire makes heat. Heat makes steam. Resin should make steam. Let's try it."

So he did and it did and does. Smoky? Yes. But the plant is all alone and the fish don't mind a smoke cloud at sea. Tubes sooty? A little, but not so much as one would think; about the same as an Illinois coal. Fuel cost? Digging and hauling a half mile by odd-job workmen who would otherwise mostly be waiting for the next job.

One funny thing though; quite some fuel melts and drops, burning, into the ashpit, so sometimes it is difficult to say which is furnace and which ashpit. Holes in the firebed aren't so bad, for they let the ashpit gases up to the heating surfaces.

Needless to say, the conditions, as well as the climate, are "unusual." This practice is not advocated as a universal method of solving the fuel problem. But it proves once more the resourcefulness of engineers in utilizing "what have you?"

THREE RIVERS draining the Pennsylvania anthracite fields—the Susquehanna, Schuylkill, and Lehigh—have been carrying away thousands of tons of combustible material annually for almost a century, says the Department of Commerce in a publication recently issued by the United States Bureau of Mines. The resulting deposits of coal in these streams have been a fruitful source for coal-dredging operations. Most of the dredge coal is recovered from the Susquehanna and its tributaries—Wiconisco, Mahanoy, Shamokin, and Swatara Creeks. The Schuylkill River is second in importance, and a small amount is also taken from the Lehigh River. The "river coal" consists chiefly of sizes equivalent to buckwheat No. 3 and boiler. Much of the dredge coal is sold for steam raising at near-by points, and in recent years it has been quite popular as a domestic fuel in Harrisburg, York, Sunbury, and other cities, for which purpose it is burned under forced draft on a wire screen or perforated plate. Prices obtained for dredge coal have declined since 1920 and have averaged slightly less than $1 per gross ton in the last five years.

Loss of Head *in* TRASH AND ICE RACKS

Analyses made at Munich and Stockholm of different types of members at various spacings and under varying conditions of flow

By Morrough P. O'Brien*

AS THE DEVELOPMENT of low-head water power sites progresses towards lower heads and larger water quantities, the reduction of the energy losses in the water passages becomes more and more important. Although the loss of head in ice or trash racks has received some attention in the past, the most thorough investigations of this subject are described in recent publications of two European laboratories, the Hydraulic Institute of the Technical University at Munich and the Hydraulic Structures Laboratory at the Technical University of Stockholm.

The Munich experiments comprise two groups, the first with the direction of flow of the approaching water normal to and the second making an angle with, a line through the plane of the racks at the water surface. The experiments made at Stockholm were similar to the first group of the Munich experiments. Both experimental programs included an investigation of the relation between the head loss and the inclination to the horizontal, the ratio of the obstructed area to the total area and the velocity of approach.

Munich Experiments

First Group.[1] These experiments were carried out in a very smooth wooden channel having a width of

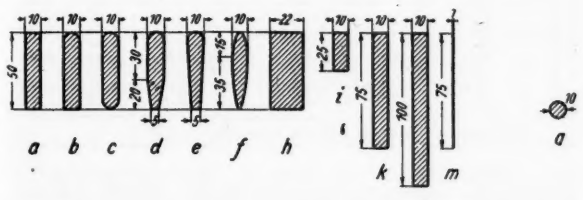


FIG. 1. CROSS-SECTIONS OF MEMBERS IN MUNICH EXPERIMENTS. DIMENSIONS IN MILLIMETERS

0.97 ft., a depth of 4.26 ft. and a length of 13.9 ft. The members of the racks were of ash and a half of a member was placed against each wall to eliminate the effect of the length. The loss of head was taken to be the difference in water level above and below the racks and was not corrected for the increase in velocity head due to the decrease in depth. This approximation introduced an error of only 5 per cent at the highest velocity. The quantity of flow for both groups was measured by a rectangular weir without end contractions.

The first experiments aimed at a determination of the effect of the spacing of the members. Rectangular members having a cross section 0.033 by 0.164 ft. were placed vertically in the channel. The number of members in the channel was changed so as to give a variation in the ratio $\frac{s}{b}$ from 1:0.87 to 1:6.45, where s is the width of the member and b is the clear spacing, see Fig. 1. The results were found to follow the general relation.

$$h_w = B \frac{V_1^2}{2g} \left(\frac{s}{b}\right)^n$$

or, for the racks in question

$$h_w = 2.42 \frac{V_1^2}{2g} \left(\frac{s}{b}\right)^{4/3}$$

where h_w is the loss of head and
V_1 is the velocity above the racks.

Effect of Varying Type of Rack

The relative efficiency of the types of racks shown in Fig. 1 was studied for a constant value of the ratio $\frac{s}{b}$ of 1:1.7 (eleven members in the channel). The values of B for the different types were:

Cross section	B
a	2.42
b	1.83
c	1.67
d	1.035
e	0.92
f	0.76
g	1.79

Using racks of a constant thickness (0.033 ft.) but varying the length of the cross section from 0.082 to 0.33 ft., there was no appreciable increase in the loss of head. Another investigation showed that for a con-

*Assistant Research Engineer, Hydraulic Structures Laboratory, Royal Technical University, Stockholm, Sweden.

[1]Kirschmer, O., "Untersuchung uber den Gefallverlust an Rechen," Mitteilungen des Hydraulischen Instituts der Technischen Hochschule, Munich, Vol. I, 1926.

stant ratio of $\frac{s}{b}$ and a constant value of V_1, the coefficient B remained the same for similar cross sections regardless of the absolute dimensions.

Effect of Inclination

Using rectangular members with a cross section 0.033 by 0.164 ft. and $\frac{s}{b} = 1:1.7$, the effect of the inclination to the horizontal was tested at angles of 90, 60, 45 and 30 deg., and it was found that the loss varies as the sine of the angle A giving the complete formula

$$h_w = B \frac{2g}{V_1^2} \sin A \left(\frac{s}{b}\right)^{4/3}$$

Using an iron rack, free of rust, of the same section as a, the loss at $\frac{V_1}{2g} = 0.065$ ft. was 0.069 ft. as compared with 0.073 for wood.

Second Group.[2] The first experiments of this group considered the deflection of the flow on passing through racks set at a certain angle to the direction of flow as shown in Fig. 2. The racks were 0.97 ft. wide and as the angle X was varied, the width of the channel of approach was necessarily changed. After passing through the racks, the water flowed into a basin 6.24 by 5.96 ft. in plan and 3.97 ft. deep. The deflection of the

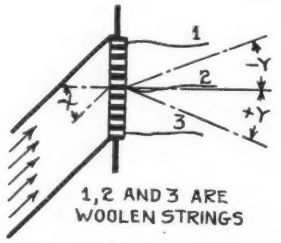


FIG. 2. ARRANGEMENT OF RACK AT MUNICH TO TEST DEFLECTION OF FLOW WHEN RACK IS AT ANGLE TO FLOW

TABLE I. RESULTS OF SECOND GROUP OF TESTS AT MUNICH TO DETERMINE DEFLECTION OF FLOW UNDER CONDITIONS OF FIG. 2

Cross-Section	Clear Spacing (mm.)	Angle Y in Degrees Measured with a Woolen String 1	2	3
		X = 60°		
a	8,7	+ 3	+ 1	− 1
	17	+ 5	0	− 3
	50	+ 4	− 3	− 10
	64,5	+ 2	− 20	− 21
c	17	+ 10	− 4	− 7
	50	+ 4	− 6	− 13
d	17	+ 4	− 5	− 6
e	17	+ 10	0	0
f	17	− 3	− 4	− 6
	32,5	0	− 6	− 11
	50	− 10	− 20	− 28
g	17	− 33	− 38	− 41
h	37,5	+ 18	0	− 6
i	17	+ 9	+ 1,5	+ 1
	50	− 8	− 7	− 21
k	50	+ 9	+ 0,5	− 4
	64,5	+ 1	− 10	− 14
		X = 45°		
a	64,5	− 6	− 12	− 17
f	50	− 8	− 6	− 12
g	17	− 14,5	− 20	− 18,5
k	64,5	+ 7,5	0	− 7

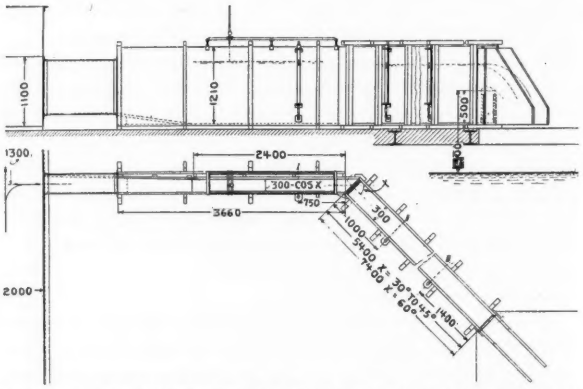


FIG. 3. ARRANGEMENT AT MUNICH FOR DETERMINING HEAD LOSS FOR OBLIQUE APPROACH. DIMENSIONS IN MILLIMETERS

TABLE II. MUNICH EXPERIMENTS: EFFECT OF VARIATION OF AREA-RATIO E, WITH RACKS OF RECTANGULAR SECTION

Rack	Number of members in channel	b	$\frac{s}{b}$	$e = \frac{b}{s+b}$	Coefficient R for x = 0°	x = 30°	x = 45°	x = 60°
A	16	8.7	1.14	0.47	2.78	4.70	4.97	6.92
B	15	10	1.00	0.50	2.29	3.81	3.95	5.28
C	14	11.3	0.88	0.53	1.95	3.05	3.54	4.90
D	13	13	0.76	0.57	1.63	2.42	3.08	
E	12	15	0.67	0.60	1.35	2.07	2.54	4.38
F	11	17	0.58	0.63	1.13	1.77	2.25	
G	10	20	0.50	0.67	0.94	1.46	2.05	4.26
H	9	23	0.42	0.70	0.78	1.22	1.82	
J	8	27	0.36	0.73	0.65	1.08	1.68	3.98
K	7	32.5	0.31	0.77	0.50	0.93	1.52	
L	6	40	0.25	0.80	0.37	0.78	1.40	3.84
M	5	50	0.20	0.83	0.27	0.69	1.28	
N	4	64.5	0.15	0.87	0.19	0.57	1.20	3.63
	Rectangular Elements 0.033 x 0.164 ft.					0.50	1.08	

TABLE III. MUNICH EXPERIMENTS: USING RECTANGULAR MEMBERS SET VERTICALLY AND A CONSTANT AREA-RATIO E = 0.63, RELATIVE EFFICIENCY AS DENOTED BY RESISTANCE COEFFICIENT R WAS TESTED

Cross Section	Coefficient R for x = 0°	x = 30°	x = 45°	x = 60°
a	1.13	1.46	2.05	4.26
b	0.86	0.76	1.29	2.45
c	0.78	0.71	1.29	2.81
d	0.48	0.43	0.94	2.19
e	0.42	0.68	1.29	3.05
f	0.35	0.22	0.67	1.84
h	1.13	1.88	2.75	5.15
i	1.13	1.81	2.72	4.26
k		1.53	2.32	3.43
l	1.13	1.62	2.12	3.88

[2]Spangler, J., "Untersuchungen uber den Verlust an Rechen bei schrager Zustromung," Mitteilungen des Hydraulischen Instituts der Technischen Hockschule, Munich, Vol. II, 1927.

flow was measured by woolen strings at points 1, 2 and 3. The results appear in Table I.

In determining the head loss, the arrangements shown in Fig. 3 were used. The head loss was computed as the true energy loss or the drop in the surface level minus the increase in velocity head. The racks were vertical.

The effect of a variation of the area-ratio e, was investigated, using racks having a rectangular section and

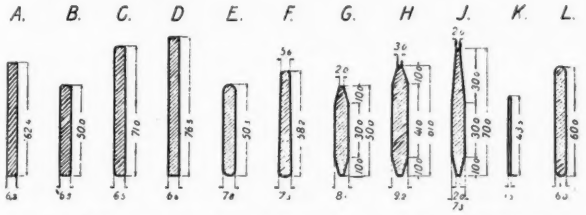


FIG. 4. STOCKHOLM EXPERIMENTS: CROSS-SECTIONS OF RACK MEMBERS TESTED. DIMENSIONS IN MILLIMETERS

the results are shown in Table II. Using a constant value of the area-ratio of 0.63, the relative efficiency of different cross sections was then investigated giving the data appearing in Table III. The symbols used are:

h_w = head loss (True energy loss)
X = angle of approach
t = s + b

$$e = \frac{b}{s + b} = \text{area-ratio}$$

$$R = \frac{h_w}{V_1^2/2g} = \text{resistance coefficient}$$

V_1 = the mean velocity

Comparing the results of the first and second series of experiments, $R = B\left(\frac{1 - e}{e}\right)^{1/3}$ for X = 0 deg. where B is to be taken from the table below.

Section	a,h,i,k,l	b	c	d	e	f	g
B	2.34	1.77	1.60	1.00	0.87	0.71	1.13

The values of the head loss shown by the second series are slightly lower than for the first due to the correction made for the change in velocity head.

Stockholm Experiments[3]

Racks tested were of iron of standard design and were furnished by various manufacturers. Their cross sections appear in Figs. 4 and 5. The experiments were made in a glass-sided channel, 2 ft. wide. Before the racks were installed in the channel, the velocity of flow was brought to a predetermined value (3.22 ft. per sec. for most of the experiments) for a depth of about 2 ft. The racks were then inserted in the channel and the depth measured 5.9 ft. upstream and 12.9 ft. downstream by means of point-gages. Each rack was tested at angles of 90, 75, 60 and 45 deg. with the horizontal. The head loss was computed by subtracting the increase in velocity head from the drop in the water surface. The area-ratio was computed for the plane of the rack and was corrected for each angle to allow for the fact that the circular lateral bracing obstructed the same area at all slopes. In Table IV, which gives the results of these experiments, the coefficient R refers to the energy loss at insertion of the racks.

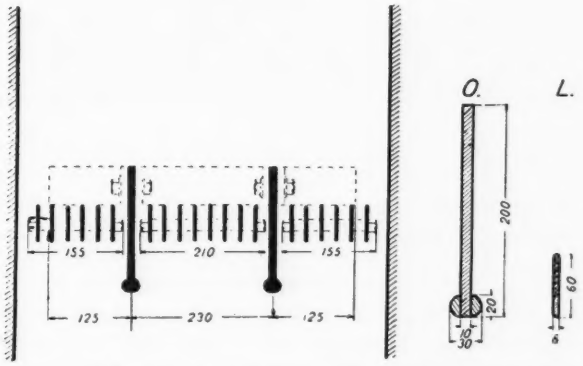


FIG. 5. STOCKHOLM EXPERIMENTS: COARSE AND FINE RACKS (LILLA EDET). DIMENSIONS IN MILLIMETERS

TABLE IV. STOCKHOLM EXPERIMENTS: WITH FINE RACKS: ENERGY LOSS R FOR DIFFERENT VALUES OF ANGLE X, ANGLE AT WHICH RACK IS SET WITH RESPECT TO LINE OF FLOW

Description of Members				Area Ratio e		Energy loss $R = h_w \div \frac{V_1^2}{2g}$ V_1 = 3.22 ft./sec. Values of R for x =			
Type	Width s mm	Length l mm	Clear Spacing b mm	Neglecting bracing	Including bracing	90°	75°	60°	45°
A	6.2	62.4	19.2	0.238	0.271	0.52	0.51	0.44	0.34
B	6.5	50.0	19.8	0.249	0.283	0.46	0.44	0.40	0.31
C	6.5	71.0	19.7	0.249	0.283	0.46	0.42	0.39	0.30
D	6.6	76.5	19.7	0.242	0.273	0.46	0.45	0.38	0.30
E	7.8	50.3	19.8	0.273	0.303	0.60	0.57	0.50	0.33
F	7.3	58.2	19.9	0.268	0.299	0.40	0.37	0.32	0.25
G	8.1	50.0	19.9	0.284	0.308	0.24	0.24	0.20	0.13
H	9.2	61.0	19.5	0.307	0.336	0.39	0.35	0.28	0.21
I*	7.3	70.0	19.5	0.268	0.299	0.26	0.24	0.19	0.16
K	1.5	43.5	19.0	0.070	0.100	0.10	0.10	0.09	
L	6.0	59.0	18.5	0.240	0.273	0.48	0.45	0.39	0.31

TABLE V. STOCKHOLM EXPERIMENTS WITH COARSE AND FINE RACKS: VALUES OF ENERGY LOSS R FOR X = 90 DEG.

Description of Members				Area Ratio e		Energy loss $R = h_w \div \frac{V_1^2}{2g}$ V_1 = 3.22 ft./sec. R for x = 90°
Type	Width s mm	Length l mm	Clear Spacing b	Neglecting bracing	Including bracing	
M	2 st.17 4 st.30	170	88	0.257	0.337	0.67
N	2 st.30 2 st.36	225	153	0.220	0.290	0.48
O	30	200	200	0.100		0.11
O+L				0.233	0.261	0.51

Racks of Types C and I were tested at velocities of 3.32, 3.22 and 3.67 ft. per sec. and it was found that the loss of head varied as the square of the velocity. The same racks were also tested with clear spacings between the members of 0.043, 0.065, 0.083, 0.098 and 0.12 ft., giving the relation that the loss varies as the 2.15 power of the area-ratio.

[3]Fellenius, W., "Undersokningar betraffande Fallforluster i Skyddsgrindar vid Vattenkraftanlaggningar," Bulletin No. 5, Hydraulic Structures Laboratory, Royal Technical University, Stockholm, Sweden, 1927.

The results of the experiments were divided into two groups:

(1) Rectangular sections with sharp corners (Sections A and D in Fig. 4) and rectangular and trapezoidal sections with slightly rounded corners (Sections B, C, F and K).

The notation is the same as above.

$$h_w = m \sin X \cdot e^2 \frac{V_1^2}{2g}$$

(2) Tapered section: $h_w = m \sin^{3/2} X \cdot e^2 \frac{V_1^2}{2g}$

Results of additional experiments on combined fine and coarse racks of the type used at the Lilla Edet power station appear in Table V. The values of m appear in Table VI.

Comparison of Results

On the assumption that the decrease in kinetic energy after passing the rack is not recovered as an increase in depth, we have the relation

$$h_w = \frac{V_2^2}{2g} - \frac{V_3^2}{2g} = \frac{V_3^2}{2g}\left[\frac{e\,(2-e)}{(1-e)^2}\right]$$

Where V_2 is the velocity between the members and V_3 is the velocity downstream; V_3 is approximately equal to V_1.

This formula may be used to explain the apparent discrepancy between the Munich and Stockholm experiments as to the power of the area-ratio. Assuming that, for short ranges of e, the function $\frac{e\,(2-e)}{(1-e)^2}$ can be represented by e^n, both the experimental series give values of n in agreement with the formula as appears in the table below. The n for the Munich experiments was obtained by placing

$$\left(\frac{s}{b}\right)^{4/3} = \left(\frac{e}{1-e}\right)^{4/3}$$

and assuming that, for a short range of e,

$$\left(\frac{e}{1-e}\right)^{4/3} = e^n$$

Range of e	n (Computed)	n (Experimental)	Remarks
0.10 — 0.30	1.27	....	.....
0.30 — 0.50	2.16	2.15	Stockholm
0.50 — 0.70	3.8	3.32	Munich
0.70 — 0.90	9.0	....	.....

The above theoretical formula must be corrected by an empirical coefficient for each type of rack and so, except for the present purpose of showing that the experiments, upon which are based these two empirical formulas, are not in disagreement, it seems to have little value. Since R, m and B are pure numbers and are as a consequence constant for all systems of measurement, the same values are to be used in computing the head loss in English units, but the formulas can only be used for the range of e included in the experiments.

General Conclusions

The two experimental series left something to be desired in that they did not include experiments with a constant velocity and width of channel and varying depth. The head loss due to the racks is made up of three factors: the frictional-resistance, the form-resistance and the wave-making resistance. The Munich experiments on the effect of the length of the cross section of the members showed that the frictional resistance is negligible as compared with the other two resistances and the experiments with a constant value of area-ratio and velocity but with different absolute dimensions tend to show that the wave making resistance is not great but the evidence on this latter question is not conclusive. The wave making resistance should have a relatively smaller effect with increase in depth.

TABLE VI. STOCKHOLM EXPERIMENTS: VALUES OF M

Type	m =
A	7.1
B	6.1
C	6.1
D	6.2
E	5.6
F	4.5
G	2.6
H	3.4
J { rough	2.7
J { machined	2.4
K	1.0
L	6.5

In the experiments described, many factors affecting the head loss under actual operating conditions have necessarily been omitted and the reliability of the results would be greatly increased if they were supplemented by field measurements. Even though the formulas given can not be relied upon to give the exact loss to be expected for a certain type of rack, the coefficients are a fairly dependable indication of the relative efficiency of the different cross sections.

Approximately 1700 different lines of manufactured products will be featured prominently in the Industrial Arts Show of the Eastern States Exposition, Springfield, Mass., from Sept. 15 to 21, inclusive, according to a recent announcement. Many of the prominent manufacturers of the country have already made reservations and the management reports that space will be at a premium this year. The Industrial Arts Building itself occupies three acres of floor space and is the largest and finest building of its kind in America. In addition, there are 22 acres of exhibition space under roof in other buildings. Notable additions to grounds and buildings for this year will be the state buildings for Vermont and New Hampshire. Work on both buildings will be begun this spring and the structures will be completed in time for the 1929 exhibition.

Man power as well as machine power can be directed to its highest state of efficiency by proper guidance and planning. It is the function of the engineer to do this.

Longitudinal Attachment of Water-Leg Introduces Severe Stresses

IN FIG. 1 IS SHOWN a cross section of the front drum, with its connected water-leg, of a steam boiler that was put on the market a few years ago. The water-leg is of

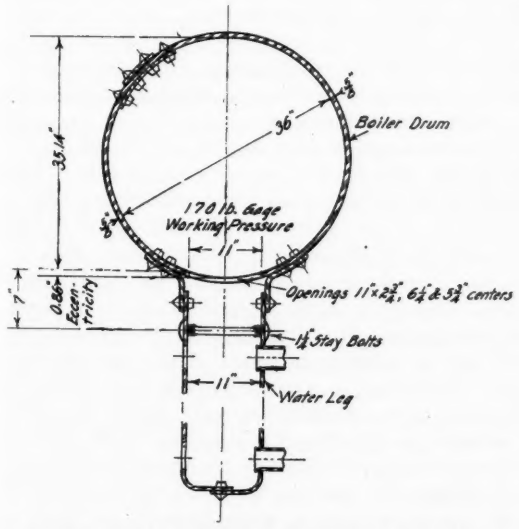


FIG. 1. INCORRECT METHOD OF ATTACHING WATER-LEG TO BOILER DRUM

the conventional type but is attached to the drum longitudinally instead of transversely. Water connection between water-leg and drum is made through holes 2¾ in. wide by 11 in. long, on 6¼ in. and 5¾ in. centers which are located in the bottom of the drum. It is evident that the ligaments between these holes were considered capable of taking purely tensile stress in the same manner as the remainder of the drum. I shall attempt to prove that this is a mistaken belief and that the construction is in the category of the old lap-seam boiler—dangerous.

Figure 2 represents the cross section of an elementary steam-boiler made up of steel plate rolled to as true a circle as is practicable and with seams riveted in compliance with state and city codes governing this kind of apparatus. The force tending to burst the shell is found by multiplying the radius by the internal pressure; in this case 100 lb. gage. The required thickness of plate is found by dividing the product of the radius and the pressure by the product of the allowable stress and the efficiency of the joint.

Now, if we enclose the shell in a still larger one and subject both to a pressure of 100 lb. gage, we have the condition shown in Fig. 3. It can readily be seen that the pressure within the inner shell is balaced, or "neutralized," by the pressure without, and the plate carries no stress excepting, of course, the slight compression

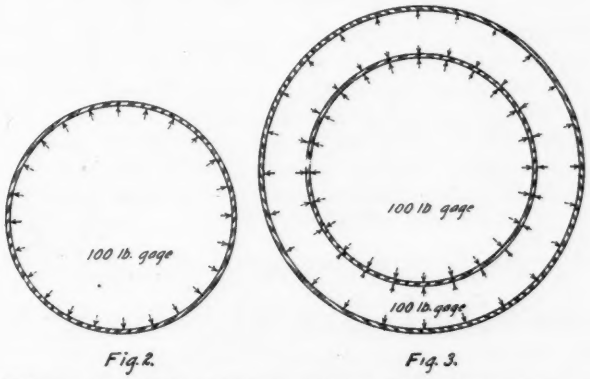


FIG. 2. ACTION OF FORCE TENDING TO BURST A SHELL
FIG. 3. EFFECT OF ANNULAR SPACE IS TO BALANCE PRESSURE ON INNER SHELL

caused by the greater diameter of the outside of the shell, and which amounts to 100 lb. multiplied by the thickness of the shell. In Fig. 4 we have riveted, or welded, two plates between the inner and the outer shells, forming a chamber in this annular space. We apply a pressure of 100 lb. per sq. in. to the interior of the inner shell and to the interior of the chamber. It is evident that the portion of the shell subject to a 100-lb. internal pressure and an external pressure of 0 lb., or atmospheric pressure, has a bursting stress similar to Fig. 1. The portion of the shell enclosed by the annular chamber, however, being "neutral" by reason of equal pressures on both sides, cannot take stress in the same manner as the rest of the shell; that is, in simple tension, so it becomes a curved tie with an eccentricity e. The stress in the portion a-a is transverse, or bending, and its amount is determined by a computation involving the pressure, the distance d, the eccentricity e, and the area and section-modulus of a unit portion of the shell.

Bursting pressure in the drum is resisted in the vertical axis as seen from Fig. 1 by the solid plate at

the top of the drum, which plate is in tension; the ligaments in the bottom of the drum, which are in transverse stress; and the stay-bolts, which are in tension. The ligaments are called upon to support their share of the pressure in the drum as well as about half the pressure on the portion of the water-leg between the ligaments and the nearest stay-bolts. The nearest stay-bolts being 7 in. away, the load carried per unit width of ligament is about $\left(\frac{35.14}{2} + \frac{7}{2}\right) \times 170$, divided by the efficiency of the ligament. In this case, the openings are 2¾ in. wide and there are two such openings per foot of length of drum, so the efficiency of the ligament is $\frac{12 - 2 \times 2\frac{3}{4}}{12} = 54.2$ per cent.

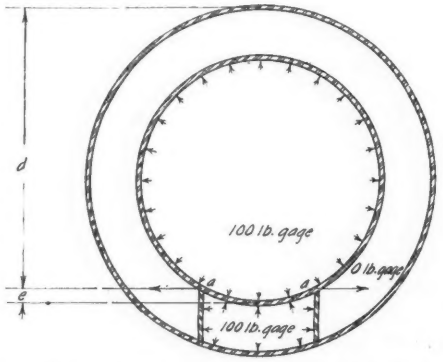


FIG. 4. DISTORTION IS CAUSED BY UNEQUAL APPLICATION OF FORCE

By the foregoing reasoning, the load per inch of ligament is $\left[\left(\frac{35.14}{2} + \frac{7}{2}\right) \times 170\right] \div 0.542 = 6610$ lb.

The eccentricity is 0.86 in. so that bending-moment is $6610 \times 0.86 = 5680$ in.-lb. As the section-modulus of a 1-in. strip of the ligaments is $1 \times 0.625^2 \div 6 = 0.065$, the stress due to bending (if it were within the elastic limit of the material) would be $5680 \div 0.065 = 87{,}400$ lb. per sq. in. To this must be added the direct stress which is $6610 \div (1 \times 0.625) = 10{,}600$ lb. per sq. in., making a total fiber stress of 98,000 lb. per sq. in. As this stress far exceeds the ultimate strength of the material, it is evident that the ligaments straighten out and transfer a large part of the load to the nearest stay-bolts. Measurements of the shell would no doubt prove it to be far from circular, indicating stresses that will become the more dangerous as time goes on. I am of the opinion that the flexure caused by the temperature and pressure variations incident to operation will some day cause failure of these boilers.

After many years of effort, the old-fashioned lap-seam boiler has been legislated out of existence, or nearly so, and it would seem an anomaly to tolerate the kind of construction described on any score other than unfamiliarity with the facts. Some manufacturers of pressure vessels seem to think that if a vessel withstands a test pressure of 50 per cent, or 100 per cent in excess of the working pressure, the vessel is sure of a long life, taking no account of the effect of repeated flexure of such elements as the ligaments in the boiler under discussion and the seams of the old lap-seam boiler.

All too frequently, the machinery erected for the protection of the public fails to function and we have a boiler explosion, a train-wreck or a ship-wreck. The cause may be ignorance or carelessness—sometimes even graft. An effect of the Workmen's Compensation Act is the protection of a certain type of manufacturer. While the operation of the law does protect the families of victims of industrial accidents, it at the same time, in a measure, keeps those responsible for the accidents from the publicity that would otherwise follow on the legal action taken by the families of the victims. Just as State Guarantee of Bank Deposits encouraged "boot-leg" banks in some states, so does the Workmen's Compensation laws encourage "boot-leg" manufacturers.

Los Angeles, Calif. C. O. SANDSTROM.

How You Do Things Is Important

TOO SELDOM is found among the information given the reader as to accomplishing a given result, do we find reference as to the how, in this case referring, not to the technique of the work but rather to the finish put on the job and the impression created upon others.

This phase of the engineer's activities has been touched upon under the heading, "The importance of good English and cleanliness in obtaining promotion." These factors are important in the impression created among one's superiors but let us not forget that our work should also have "eye value" and that a neatly finished piece of work, even though it takes longer and costs more, remains ever as a reminder of our ability.

"It isn't only what you do, it's how you do it." It is logical that the better impression one makes on the boss the more likely he is to receive a raise in pay and rapid promotion. In all dealings with him and others, strive ever to be the gentleman. This does not require a lot of schooling or study, for one can develop the ability to express himself correctly simply by reading the articles in his favorite magazine since these are usually well written. Nor is a servile attitude required, for the bigger the man the more courteous we find him.

We all know that an engineer will get dirty and covered with dust and grease at times but should he stay that way continually? It costs only a little time and soap to get spick and span after the job is finished.

In small plants, most engineers do the repair work not only in the boiler and engine rooms but also throughout the factory or works. Often it is the attitude an engineer has toward this outside work that makes or breaks him and he should take care to give his work a good appearance. Perhaps the machine repaired or installed will work no better, although it often does, but a classy looking job is a daily reminder to the manager or superintendent that the engineer "knows his stuff."

Gaining advancement is largely a matter of creating a good impression with one's superiors and then maintaining that reputation till the opportunity comes, as it always will, to step up in his own organization or in another. It isn't sufficient just to be a good engineer. One must show by his work that he is good and then keep the boss aware of that fact. When you have ability, why try to hide it behind an uncouth manner and a poor appearance?

Often we hear of the manager or superintendent who refuses to purchase equipment for the power plant operator so as to enable him to check and improve operation. May not the fault be with the engineer, who probably did not present his request in the proper way or consider the installation from the other fellow's point of view? Should any engineer reading this feel that he needs a certain piece of apparatus in his plant, let him sit down and make a list of the advantages or savings made possible with the apparatus and then determine the exact cost of the installation. Now write a letter embodying this information and lay it on the manager's or superintendent's desk. If you can show him where it is advantageous to buy the apparatus, he will buy it and thank you for suggesting it. It's simply the idea of getting all the facts over.

It is regrettable that the operating engineer makes so little effort to dignify his work and gain for himself the respect that is his rightful due. Gone are the days when it required only a strong back and the ability to start a steam engine to qualify as an engineer but too many men feel that passing a test for a license proves them masters of a science that is ever advancing and leaving them years behind. From the writer's observation, many operating men feel that they know enough and neglect to keep up to date, thus settling into a rut, bemoaning their fate. Let's all get busy and put the idea over that the engineer is an important factor in business; that as such he deserves proper respect and remuneration. And remember it will be found that it isn't only what you do but how you do it that counts.

Philadelphia, Pa. THOS. W. BENSON.

Pulverized Coal—How Fine?

ALTHOUGH I DO NOT profess to be an authority on pulverized coal or on combustion subjects in general, I wish to take issue with some of the arguments contained in the article by H. G. Lykken in the March 1 issue entitled, Pulverized Coal—How Fine?

My understanding is that the combustion of pulverized coal and atomized oil are much the same. It is generally acknowledged that the more thorough the atomization of oil the better the combustion, because, the more finely divided the oil is, the closer its approach to the ideal gaseous state.

In a measure, isn't the same true of pulverized coal? The finer the pulverization the closer the approach to the ideal gaseous state, although, of course, it is first necessary to convert it into the actual gaseous state but the same is also true of oil. Except for increase in cost, the arguments that Mr. Lykken brings to bear against finely pulverized coal should be equally applicable against finely atomized oil.

My contention is that the finely atomized oil would also form a cloud which would obstruct radiant heat penetration just as effectively as the cloud of finely divided coal mentioned by Mr. Lykken. I do not know the exact fineness of dust which settles in coal mines, grain elevators and flour mills, but it is exceedingly fine. Give it a chance and it burns with great violence. The finer the dust, the greater the violence of the explosion. I believe that coarse coal particles such as recommended by Mr. Lykken would hardly be dangerous in the form of dust. They do not ignite and burn with sufficient ease.

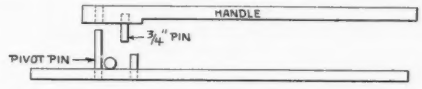
Besides, a 200 mesh sieve does not give one a real fineness test these days. The maximum of fineness is a 400 mesh sieve having 160,000 sq. openings per square inch which has recently been developed and built into sieves by an American manufacturer. These very fine sieves are not yet used in standard tests, that is true, but they are being used by the manufacturers of cement, for instance, who for their own information wish to know just how fine their cement is and I anticipate that, eventually, the 400 mesh sieve will be used in testing the fineness of pulverized coal.

Newark, N. J. W. F. SCHAPHORST.

Simple Eye Making Device

EYES FOR PIPE HANGERS or other purposes may be easily and quickly made by common labor, thus saving the time of a blacksmith, by use of the simple device illustrated in the accompanying sketch.

This device consists of a block made of flat iron stock which is supplied with two pins 1¼ in. apart.



HANDLE WITH ATTACHED PIN ENGAGES ROD AND TWISTS IT FORMING EYE

The pivot pin is made long enough to pass through the handle which is also made of flat iron stock and has a hole for reception of the above mentioned pin and a ¾-in. pin as shown. The rod to be bent is placed between the stationary pins on the block, which is held in a vise and the handle is placed over pivot pin and turned in a circle toward the short end of the block. A perfect eye can be made by this means after a few trials.

Snoqualmie Falls, Wash. J. W. BEST.

Engine Speed Change Limitations

IN HIS ARTICLE "Relation Between M.E.P. and Engine Speed," on page 317, Mr. Mason's figures are in the main correct, but incomplete. His solution of how to obtain earlier cutoff would never pass the examiners unless carried out a step farther. Suppose that the engine speed were such that the rim speed of the flywheel approached 6000 ft. per min., would he insist that an increase of 20 per cent in speed was the proper solution? My own reply to the examiner would be, "In some cases, the engine speed may be increased to secure earlier cutoff, provided that the increased speed will not be beyond the safe rim speed of the wheel."

Suppose that the engine was driving an alternator in parallel with other units, it appears to me that weighting the governor for increased speed would cause the engine to take a larger share of the load and would not tend to make the cutoff any earlier. As to the increased steam flow with increased speed, it would depend upon the ratio of expansion already carried out before changing speed. At initial pressures around 150 lb., Marks gives the number of expansions as 7 for best economy, in simple condensing four-valve engines. While condensation loss is increased at early cutoff, at the same time the loss due to incomplete expansion is markedly reduced.

Springfield, Mass. A. F. SHEEHAN.

Questions and Answers

Flat Plate Orifice for Flow Measurement

WHERE SHOULD THE tap holes on both sides of the orifice plate of a flat plate meter be located when the size of orifice is known and what formulas are used?

E. S.

A. Fundamentally, the operation of this meter depends upon the fact that the total energy at the various

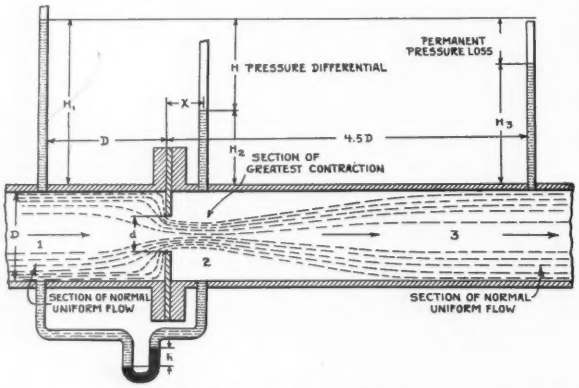


FIG. 1. CROSS SECTION OF A TYPICAL FLAT PLATE ORIFICE INSTALLATION, SHOWS ACTIONS OF FLUID

sections remains constant and is equal to the sum of the pressure energy and the velocity energy at any section.

If d in Fig. 1 is equal to 0.5D, the velocity at section 2 must be four times that of section 1. This increase in velocity takes place at the expense of pressure and a manometer connected across sections 1 and 2 would show a pressure difference, the lower pressure existing at section 2. Due to the action of the jet, it continues to contract for some time after passing the orifice, the section of least area being called the vena contracta. As this represents the highest velocity and lowest pressure, a manometer connected across this, section 2, and up-stream side section 1, shows the greatest pressure deflection for any given flow.

Two pressure taps are necessary. The high pressure or upstream tap at section 1 is always located one pipe diameter above the orifice; the downstream or low pressure one is located at the vena contracta, section 2, its location varying with the orifice ratio. For ordinary ratios, a distance of ½D is satisfactory, the exact location being given as the distance taken from Fig. 2. Considerable variation is allowable in the location for lower ratios without affecting the reading, but, at higher ratios, around 75 to 85 per cent, slight variations are noticeable in the results. Pressure taps on permanent installations should be ⅜ in. but, for temporary work, especially on small pipe sizes, ¼-in. taps are easier to install and use.

Flow through the orifice can be calculated from the fundamental formula $V = CM\sqrt{2gh}$ which may be simplified for various services as follows:

$$G = 5.69\ C\ D^2\ \sqrt{h} \quad (1)$$

$$W = 359\ C\ D^2\ \sqrt{h \div v} \quad (2)$$

$$F = 129\ C\ D^2\ \sqrt{hP \div T} \quad (3)$$

where:

G = g.p.m. of water (50-110 deg. F.)
W = lb. of steam per hr.
F = cu. ft. free air per min. (14.7 lb., 60 deg. F.)
V = specific volume of steam from tables
P = initial pressure, lb. per sq. in. abs.
T = F deg. abs.
C = coefficient from Fig. 3
D = internal pipe diameter in inches
h = differential head in inches of water

In addition to the variation of C with the orifice ratio, there is a slight change with pipe diameter. The curve gives coefficients for a 6-in. pipe but these values will give results of sufficient accuracy for pipe ranging in diameter from 3 to 12 in.

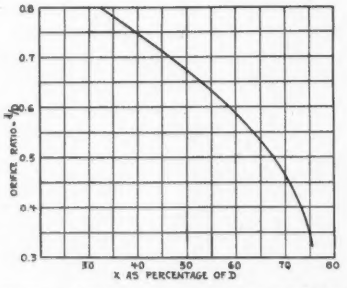


FIG. 2. EXACT LOCATION OF THE VENA CONTRACTA VARIES WITH THE ORIFICE RATIO USED

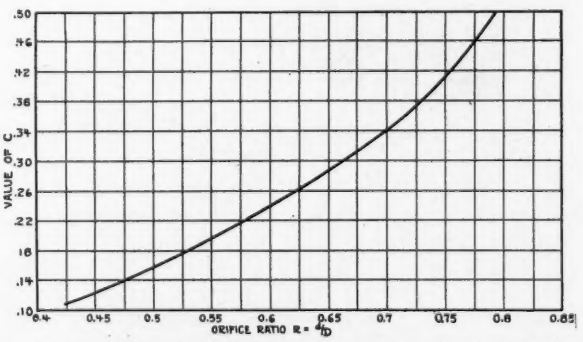


FIG. 3. ORIFICE COEFFICIENT C VARIES WITH THE ORIFICE RATIO AS SHOWN

Taking an example: Suppose an orifice 3 in. dia. is to be installed in a pipe line whose measured internal diameter is 6 in. Compressed air at 100 lb. gage is to be measured and the installation is at sea level. The upstream pressure tap should be located 6 in. from the orifice and from Fig 2, the down stream tap should be placed 0.675 D or about $4\frac{1}{16}$ in. from the center of the flange. From Fig. 3, C will be 0.158 and D^2 and P will be 36 and 114.7 respectively. From measurements, the temperature has been found to average about 115 deg. F. or 575 deg. abs. and the meter, when set up, shows a mercury deflection of 1.2 in. which is equal to $1.2 \times 13.6 = 16.3$ in. of water. Substituting these values in equation 3 gives a flow of 1325 cu. ft. of free air per minute. Applied to conditions other than sea level, the final result must be corrected from the standard condition of 14.7 lb. and 60 deg F. to the actual conditions of the installation, if the flow is desired in cubic feet of free air.

Tests for CO_2 Leakage in Refrigerating Systems

WE ARE LOSING a great amount (about 50 lb.) of CO_2 gas daily although no leaks have been found after carefully going over every joint and the seven valves. The condenser was recently retubed and repacked. We operate a 20-t. CO_2 ice machine which serves a calcium chloride brine tank and a double pipe brine cooler. The brine is circulated through the building by means of a pump. A test on the double-pipe cooler showed no leaks and there are no bubbles in the brine tank.

2. Will it be advisable to test the condenser and coils with ammonia? Will the trace of ammonia left in the pipes interfere with the CO_2 gas?

3. How can the quality of CO_2 gas be determined when delivered in the cylinders?

4. Will CO_2 gas lose its pressure effect in operation when it comes in contact with water, ice or brine?

5. Will CO_2 leave any trace, in case of a leak, in the brine tank? What are the best tests for this kind of trouble? C. R.

A. If you are losing about 50 lb. of gas daily, there must be a leak somewhere. Although your condenser and brine cooler have just been retubed, there is a possibility of the new tubes being defective if they were not tested before being installed.

To test the condenser water for CO_2 leak, take a sample of the water after it has gone through the condenser and put several drops of barium hydroxide into this sample. If any carbonic acid gas is in the sample of water, the barium hydroxide will throw down the carbonate and make the sample of water cloudy. This instantly indicates that one of the condenser water tubes is leaking and the leak should be traced to its source and the tube replaced.

Barium hydroxide cannot be used for testing the calcium solution as in the case of the condenser water, however, a mechanic particularly experienced in this line of work can quickly find the leak. Manufacturers of CO_2 equipment usually have such experts in their employ. It is advisable, therefore, to call upon them for service.

2. It would not be advisable to use ammonia for finding leaks, although it is not believed that the ammonia would interfere with the CO_2 gas in the system. It is likely that there would be considerable loss of ammonia during transfers if it were used as suggested.

3. Reliable companies selling CO_2 gas are glad to test the gas for their customers on request and submit a complete report as to its quality.

4. There is no occasion for the CO_2 gas to come in contact with either water, ice or brine.

5. Except for the disturbance of the surface of the brine caused by leakage of CO_2 gas into the brine tank, the gas will leave no trace in the brine tank.

Overall Efficiency Measurement

WHAT IS THE formula for determining the efficiency of a pump and motor when the suction lift in feet, the quantity of water discharged in gallons, the discharge pressure in pounds per square inch and the power consumed in kilowatts are known? J. K.

A. To measure the overall efficiency of a pump and motor, we first find the energy output by the pump and divide this by the energy input to the motor. These two must be in the same terms, that is, in the case before us it may be best to convert all units into foot-pounds.

Energy output is, therefore, the sum of the two heads in feet, suction S and discharge D, multiplied by the weight of the water discharged in pounds per minute and the energy input will be the kilowatts input multiplied by 1.34 in order to turn kilowatts into horsepower and this by 33,000 in order to obtain this in terms of foot-pounds per minute.

We presume that the suction head S is given in feet. The discharge head D will be the pressure head in pounds divided by 0.433 since 1 ft. water = 0.433 lb. per sq. in. Since 1 gal. water weighs 8.35 lb., the weight of the water W discharged will be 8.35 times the number of gallons.

Our efficiency formula is therefore:

$$E = \text{output} \div \text{input}$$

$$= [(S + D)\ W] \div (\text{kw.} \times 1.34 \times 33{,}000)$$

Exhaust Steam Injector Action

PLEASE EXPLAIN THE theory of how an exhaust steam injector pumps water into a boiler against 80 lb. pressure? M. J. M.

A. In order to meet the new conditions, the steam nozzle of an exhaust steam injector is enlarged and a central spindle is added which, when the pressure of the boiler into which the feedwater is delivered exceeds 75 lb., is made hollow so as to admit a supplementary jet of live steam from the boiler. The feedwater should flow to the injector and its temperature should be as low as possible, never under any conditions above 92 deg. With the supplementary jet and cold feedwater, the injector will feed against pressures up to 150 lb. and without the supplementary jet, against 90 lb. Increasing the temperature of the feedwater somewhat diminishes these pressures.

COST OF ELECTRIC service can be divided into two general classifications: fixed charges, which are the same regardless of volume of business; and operating expenses, which are governed almost directly by the volume of business.

Editorial Comment

Names for Things

As new equipment is developed and comes into use names have to be found so that they can be talked about understandingly. Sometimes these are coined by manufacturers of the equipment; sometimes they are just "shop talk" adopted by users. Frequently they are called one name by the manufacturers, based on a production symbol and given a nickname by users, which may be as unaccountable as the nicknames which boys wish on their chums.

Prevalence of slang in American talk and newspapers is evidence that "United States" is a live language and that those who use it submit to no dictation as to their words. It would seem, however, that in technical matters agreement as to names would help and, in most cases, such an agreement is finally reached.

Just now there is a question up of designation of three classes of thermometers which depend for their operation on, (a) expansion of liquids, such as mercury or alcohol, (b) vapor tension of volatile liquids, such as ether, sulphur dioxide or methyl chloride, (c) expansion of a gas such as nitrogen. Calling them Class I, Class II and Class III, as has been done by some makers is, possibly, simple but is not descriptive enough to carry an idea to the man on the job.

In the interest of future clarity, it would be desirable to establish names in themselves explanatory of the various types and we invite suggestions from readers of Power Plant Engineering as to names now used in plants to distinguish these three types or suitable names which are short, distinctive and easily associated with the apparatus. Letters to the editor will receive careful attention and results will be forwarded to the A. S. M. E. Power Code Committee which has the matter under consideration.

Progress in Lightning Research

No ordinary phenomenon occurring in nature is, perhaps, more awe inspiring than natural lightning. Small wonder that primitive man regarded it as an expression of the wrath of the gods and bowed down in abject terror before its mystery. Lightning was inexplicable. Even the logical mind could find no natural cause to which to attribute it. Electricity was unknown, hence lightning remained a mystery.

Yet, today, no phenomenon in nature is regarded by civilized people with more unconcern. Storms, floods, earthquakes, we still have to fear and when they transpire there is little we can do to mitigate their destructive effects, but with lightning an entirely different attitude prevails. Lightning, true enough, still holds an element of danger but perhaps no more than riding in automobiles or railroad trains or walking about city streets. We accept lightning as a matter of course.

This attitude is due less to anything we have done to make lightning less destructive than to the fact that its mystery has been removed. We know what it is, that is, we know that it is an electrical discharge brought about by the neutralization of opposite electrically charged bodies. The average man doesn't know even this but he is satisfied in knowing that it is "electricity."

While others before him suspected its true nature, Franklin was the first great adventurous soul to have the presumption to test his ideas and appropriately enough he unlocked lightning's first secret by means of a door key.

During recent years in the scientific laboratories of the world many other secrets of lightning have been unlocked, by means of a different kind of a key—a key known as the cathode ray oscillograph. By means of this marvelous device, we have compelled lightning to write its autobiography and a more intriguing narrative has never been written. Last summer in two widely separate parts of the United States, two of our leading electrical manufacturing companies set up equipment for measuring and photographing actual lightning waves and in both instances success was attained. The photographs obtained were truly speaking likenesses. They spoke volumes to the electrical engineers who examined them, who straightway went to their laboratories and wrote "The Capture of a Lightning Flash," a romance of the first order.

Perhaps the most amazing thing which the electrical engineers have discovered about lightning is its quickness, in fact if it were not for this quickness, lightning would not be the awe inspiring phenomenon that it is. As a matter of fact, the actual amount of energy released in the ordinary lightning flash is only in the order of 4 kw-hr., that is, about 30 cents worth of electricity at prevailing retail rates. It is the rate at which this 4 kw-hr. is expended, however, that makes lightning so destructive. As pointed out by Mr. Peek in the article on lightning research in this issue, these 4 kw-hr. are expended in a few millionths of a second. In other words, the power in the lightning flash is about *a thousand billion horsepower!* This is hundreds of times more than all the power in the world being dissipated continuously.

Perhaps of even greater importance than these measurements of actual lightning phenomena is the development of equipment for producing what may be termed artificial lightning. In this issue is described a lightning generator by means of which Mr. Peek recently produced lightning discharges of 5 million volts potential. While this is only a fraction of the potential reached in natural lightning discharges, these discharges have exactly the same characteristics as those found in nature. By impressing such lightning waves on transmission lines and noting by means of the cathode ray oscillograph, their effect on apparatus connected to the line, great progress has been made in developing means for protecting lines and equipment from the destructive effects of natural lightning. This, after all, is the fundamental object of all lightning research. While thus far

the lightning proof transmission line has not been constructed, Mr. Peek seems to think that, by applying the knowledge we have gained from lightning research, such a line is feasible.

Splitting Hairs in the Hydroelectric Plant

Superficial observation of the field of hydraulics and particularly of hydroelectric generating plants often leads the layman to the conclusion that little development has taken place during the past decade. Even to engineers interested primarily in steam power, the hydroelectric plant of 1929 usually looks just about the same as the plant of 1919. It is not at all the same, as every hydroelectric engineer knows. But the differences are rather in refinements of detail than in fundamental types of equipment. Developments have not been as spectacular here as in the steam plant during the past few years. They have been made, nevertheless, by careful attention to small details.

This careful attention is especially necessary in the development of extremely low-head water powers, which has been made possible largely through the introduction of the propeller type of runner. In such cases, where the total head to begin with may be only 8 or 10 ft., it is important that every passage through which the water is conducted to the wheel and away from it shall be made in such a way as to reduce loss of head in the passage to the absolute minimum.

Water passages of a hydroelectric plant may be considered to begin at the ice and trash racks ahead of the penstock or intake opening. It may seem like splitting hairs to wonder how much head is lost at this point, whether this loss is influenced by the angle at which the water enters the racks or by the proportions of the rack bars themselves. Yet it is just such hair-splitting that makes the modern low-head hydroelectric plant possible.

In this issue, Morrough P. O'Brien presents a most complete and able discussion of two series of tests on ice and trash racks, one series conducted at Munich and one at Stockholm. While the tests neglected several of the factors affecting head loss in racks under actual operating conditions, they do determine some coefficients that give a fairly dependable indication of the relative efficiency of the different cross-sections tested. Such tests, theoretical as they may be, afford at least a basis for further work. So far as we know, not much investigation of this type has been done in this country; considering the prevailing interest in low-head developments and propeller wheels, further investigation of racks, draft tubes and other details seems warranted.

Manufacturers of water-wheels have, of course, done considerable testing work on wheel models and two or three public utility companies have established laboratories for tests of hydraulic structures. But many problems, similar to the one noted above, still remain uninvestigated. They are usually problems of the hair-splitting type but, as every hydraulic engineer knows, it is this very hair-splitting,—modifying a draft-tube line a fraction of an inch, changing the shape or angle of a wheel vane and so on,—that has brought the hydroelectric plant to its present condition of comparatively high efficiency.

Power Plant Engineer's Debt to the Chemist

To determine in dollars and cents just what the power plant industry owes to the chemist for increased economy of operation over the period of the 10 yr. just past is, of course, impossible but a little consideration of some of the results of chemical research in this field will be enlightening.

Take for example the progress in the efficiency of combustion as it takes place in the boiler furnace. A comparatively few years ago it was common to find plants operating continuously with a flue gas analysis showing 6 per cent CO_2 and the very best plants were unable to get more than 12 per cent CO_2 in their flue gas without the presence of combustible gases. Today 15 per cent CO_2 in the flue gas is maintained continuously in plants of modern design. The resultant saving of fuel is enormous. This has come about by a better understanding of combustion processes, temperature control, air control, turbulence of gases, fuel conditioning, fuel characteristics and combustion rates.

Feedwater treatment has made wonderful progress. From the cut-and-try methods largely in vogue 15 yr. ago, the chemist has led the way to scientific treatments that have eliminated scale, foaming and priming with their accompanying dangers and time out for cleaning boilers, the practice in some plants being to open the boilers for inspection only once a year. These treatment processes are applicable to all sizes of plants and a visit to a great many boiler plants will reveal that the boiler scale problem has been practically solved in plants generally.

During the early days of the practical use of superheated steam, the discovery was made, after a number of disastrous accidents, that cast-iron valves and fittings were not suitable for this class of service. From that day to this, metallurgy has been the principal key to our increasing steam pressures and temperatures and the art of power generation is still handicapped by the lack of metals that will endure the high temperatures desired for economical use of steam. This statement applies not only to metal for boilers but to that used in piping, valves, fittings, turbines, engines and control equipment.

Other lines in which chemistry has served in the solution of perplexing problems confronting power plant operators are the securing of better lubricants, the prevention of corrosion and electrolysis, development of heat and electrical insulating materials, perfection of refractory materials and cements. All these accomplishments in which chemistry has played an important part have been necessary to bring the efficiency and safety of the power plant up to their present stage and a better understanding of chemistry and how it can serve in the solution of power plant problems will in many cases suggest ways out of difficulties that are extremely simple and economical. Although it can not be expected that a power plant engineer should be a scientific chemist, he can without difficulty become familiar with the general principles involved in his work and in this way equip himself with an extremely useful tool.

A LAUGH IS WORTH a hundred groans in any market. —Lamb.

Power Plant Engineering Developments and News

Multiple-Feed Lubricators for Oil and Grease

TWO MULTIPLE-FEED lubricators recently placed on the market by the American Pump & Tank Co., Cincinnati, Ohio, are shown herewith.

The Model N lubricator, shown in Fig. 1, is designed especially for machine tools, punch presses, industrial

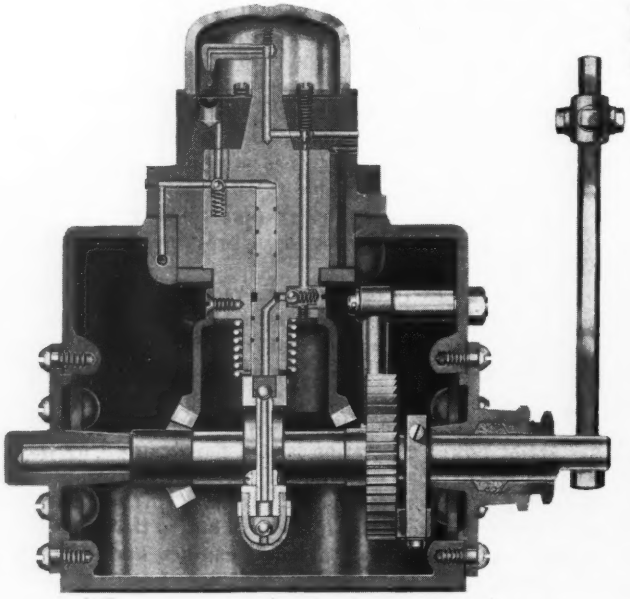


FIG. 1. MODEL N FORCE FEED LUBRICATOR

presses, calenders, textile machinery, and so on. The principal feature of the device is that a single pumping unit discharges oil in sequence into 8 feed lines and that each feed line is individually adjustable. Moreover, each setting is designed to be regulated while the machinery is in operation and the lubricator can be filled while in operation.

To secure this result, a lubricator drive arm actuated from some reciprocating part of the machine that is to be lubricated sets into a sleeve extending into the oil tank. On the end of this sleeve, the ratchet pawl engages in the ratchet wheel and changes the reciprocating motion to a rotary motion. The ratchet wheel rotates the cam shaft extending the entire length of the tank and on this shaft the cam is mounted.

Rotation of the cam raises the plunger and the spring acting on the plunger foot lowers it. On its suction stroke the plunger draws oil out of the reservoir through a foot valve and suction tube into a common port. On the discharge stroke, the pressure closes the check in the foot valve and the oil is forced through the port in the piston and through the drip nozzle into one of the openings in the cylinder. On the suction stroke the top plunger draws the oil into a common port but on the discharge stroke the ball closes and the oil is forced through a port in the cylinder into the oil line.

The piston is rotated by a set of gears driven by the cam shaft and is so timed that the port in the piston meets the port in the cylinder when the plunger makes its discharge stroke. The quantity of oil fed at each

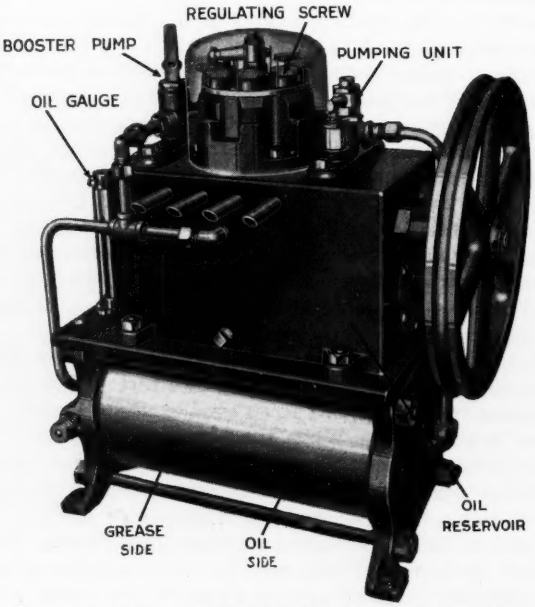


FIG. 2. MODEL P LUBRICATOR FOR GREASE AND HEAVY OIL

stroke of the plunger is regulated by the adjusting screw in the cylinder. The lubricator can be set to feed a minimum of one drop or a maximum of seven drops to one stroke of the plunger. The unit is built in multiples of 8 feeds. Since it is actuated from some reciprocating part of the machine it starts and stops with it and is designed to provide entire automatic lubrication whenever the machine is in use and to shut off the flow of oil when the machine stops. It can be supplied with either lever or rotary drives and in sizes of 8, 16, 24 and 32 feeds, or even larger if necessary.

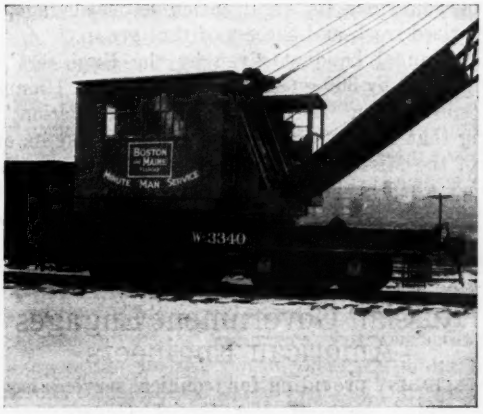
Model P lubricator, shown in Fig. 2, is designed to handle grease and heavy oils for the lubrication of bearings and gears on all types of machinery. The mechan-

ism is similar in principle to that of the Model N unit described above, in that a single grease pump supplies grease in suction to eight ports. Below the grease pumping unit is a grease cylinder as shown in the bottom, in which is a piston for grease on one side and oil on the other.

An oil reservoir contains a pumping unit which forces oil into one side of the grease cylinder and discharges an equal amount of grease into the grease pumping unit. The amount of grease being discharged by each line is individually adjustable and the unit can be furnished either with lever or rotary drive. A bypass relief valve is provided for automatically bypassing the oil back to the reservoir in case the grease consumption is less than the amount of oil pumped. The Model P lubricator can be furnished in 8, 16, and 24 feeds with grease capacities of 8½, 16 and 24 lb. respectively.

Link-Belt Gasoline Locomotive Cranes

ANNOUNCEMENT of a complete line of locomotive cranes designed especially for gasoline Engine, Diesel Engine or Electric Motor Drive, to be known as the "L" Type Crane has recently come from Link-Belt Co., Chicago, Ill. They are not merely modified steam cranes, but are designed throughout for the entirely



GASOLINE CRANE FOR USE IN RAILWAY YARDS

different and much more severe conditions imposed by a power unit running continuously at its full operating speed.

In design, the machinery and its arrangement are particularly adapted to direct engine or motor drive and all clutches, brakes, shafts, bearings and gears are oversize in order to give the best operating results and the lowest possible maintenance expense, under these conditions.

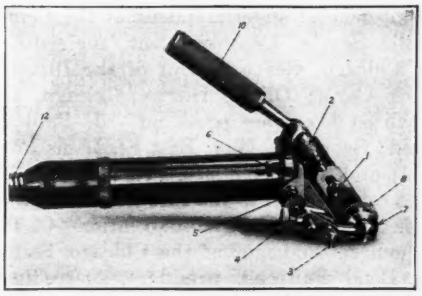
From engine or motor a totally-enclosed silent chain drive is employed and all upper frame gears have machine cut teeth, cut from solid blanks. This makes a quiet, smooth operating machine of high efficiency.

It is furnished with two-speed travel gear to give a high travel speed for traveling light and a slower travel speed for pulling heavy loads or ascending comparatively steep grades. The two-speed travel gear in no wise affects the other speeds of the machine (hoisting, boom hoisting and rotating), which should, under all conditions, remain unchanged in order not to affect the operating speed and handling capacity of the machine.

Ideal Commutator Mica Undercutter

BEING SO SMALL that it can operate in a space only 3½ in. wide, the new motor driven Ideal commutator mica undercutter offers a tremendous advantage in that no time need be spent in dismantling brushes, brush boxes and brush rigging and no time need be spent in reassembling before putting machines back into service.

In the design, a tension screw is used to hold the adjustable depth gage which is lowered and raised by



MICA UNDERCUTTER THAT CAN BE USED BETWEEN BRUSHES

means of a micrometer adjusting screw. Another micrometer adjusting screw is used for setting the roller guide the proper distance from the cutter and a tension screw is provided for holding the roller guide. To make replacement of cutters easy, a tension screw is used to permit the entire roller guide assembly to be rotated. A micrometer adjusting screw raises or lowers the roller guide to conform to size or diameter of cutter used. The depth gage is next to the saw so that the actual depth can be instantly measured and a wide surface gives bearing support without marring the copper.

This device is the product of the Ideal Commutator Dresser Co. of Sycamore, Ill.

ORGANIZATION of the Des Moines Valley Electric Co., a hydroelectric power plant enterprise, is being completed and work will be started within a short time upon its 22-ft. dam on the Des Moines river, four and a half miles south of Kalo. The project has been adequately financed by Ft. Dodge capital, said Frank Maher, Ft. Dodge attorney promoting the enterprise, although it is possible that later common stock will be offered in the communities adjacent to Ft. Dodge which the firm will serve. The Byllesby Engineering and Management Corp. engineers have finished a three-months survey of the territory affected by the power lake upon which settlements for claims will be made. The Des Moines Valley Electric Co. has completed contracts for electric power, wholesale, which will be furnished to communities it plans to serve, pending completion of the hydroelectric plant and its operation.

Illinois Utilities Meet at Springfield

ANNUAL TWO-DAY sessions of the Illinois State Electric Association, Illinois Electric Railways Association and Illinois Gas Associations, held in the Hotel Abraham Lincoln, Springfield, Ill., March 14 and 15 were attended by 1000 representatives of those groups from all over the state. For the first time, the associations presented exhibits and displays in conjunction with the meeting, several months being spent in gathering and selecting working models of the latest and most modern machinery and equipment in use in the field. The displays were shown in the Elks' club and were supplemented by charts and graphs, which attracted wide attention and will probably become an integral part of future gatherings.

Officers of the various groups were elected as follows:

Illinois State Electric Association—E. F. Kelly, Springfield, general superintendent of the Central Illinois Public Service Co., president, succeeding J. E. Johnson, Chicago, vice president of the Illinois Power and Light Corp.; Oliver Hogue, Chicago, Commonwealth Edison Co., vice president. J. Paul Clayton, Springfield; George P. May, East St. Louis Power and Light Co.; and R. S. Wallace, Peoria, Central Illinois Light Co., were elected to the executive committee.

Illinois Electric Railways Association—C. H. Jones, Chicago, general manager of the Chicago, South Shore & South Bend Railroad, president, succeeding R. F. Palmblade, Peoria, Illinois Power and Light Corp.; G. A. Richardson, Chicago Surface Lines, and R. B. McDonald, Tri-City Railway Co., Moline, vice presidents; executive committee, A. P. Titus, Springfield, John Egolf, Chicago, Aurora and Elgin Railway Co. and J. R. Blackhall, North Shore Lines, Highwood, Ill.

Illinois Gas Association—E. E. Lungren, Aurora, chief engineer of the Western United Corp., succeeding J. A. Strawn, Peoria, Central Illinois Light Co., president; H. T. East, Public Service Co. of Northern Illinois, Chicago, vice president; executive committee, M. L. Harry, Decatur, Illinois Power and Light Corp., B. J. Mullaney, Peoples' Gas Co., Chicago, J. A. Strawn, Central Illinois Light Co., Peoria, and E. G. Alexander, Dixon, Illinois Northern Light Co., executive committee. George W. Schwaner, Springfield, was re-elected secretary-treasurer of the three groups.

Governor Louis Emmerson, who addressed a joint meeting of the groups the final day, stated that his administration was committed to an insistence that the laws regulating public utilities operation be administered by the Illinois commerce commission in such a manner as will result in the greatest benefit to the public and the fairest and most intelligent treatment of the utilities. "There will be no attempt to play politics with commission rulings," he said.

Tendency to decentralize industry so that it might spread out and take advantage of favorable conditions and the part utilities play in this trend, with possible greater participation in the future, were themes of the address by James D. Cunningham, Chicago, president of the Illinois Manufacturers' Association.

Codification of rules for construction of inter-city light and power lines will advance the day when the isolated farm of the state will receive electric service equal to the service given the city dweller, declared J. D. Roberts, chief engineer of the Central Illinois Public Service Co., Springfield. He said that the majority of 15,000 Illinois farms, which are now being served by electric power, are receiving their power from high-voltage transmission lines. Construction of large centrally located generating stations, serving neighboring communities by high-power transmission lines, is solution of the problem, he said, and pioneer plants in this field are already making rapid progress in the rural electrification field.

The necessity of keeping informed of industry progress was emphasized by Alexander Forward, secretary-treasurer of the American Gas Association, New York City, who said that an industry, like an individual or company, must know facts concerning costs, sales and markets and be able to interpret them intelligently.

Utilities must do all in their power to reduce actual output costs and overhead expenses, and should seek more publicity, including advertising, and that every utility must exert its best effort in salesmanship.

Among other speakers at the event were: Paul S. Clapp, managing director of the National Electric Light Association, New York City; J. W. Welsh, general secretary, American Electric Railway Association, New York City; Dr. Franklin H. Martin, director general of the American College of Surgery; John F. Gilchrist, Chicago, vice president of the Commonwealth Edison Co., chairman of the Illinois committee on public utility information since its organization a decade ago, who summarized work and success of that group.

The annual banquet given by the Engineers' club was attended by 300 guests; John B. Maling, Hammond, Ind., spoke upon "Freak and Class Legislation," declaring that most of the freak legislation had its origin west of the Missouri River where there are no great industrial centers and where few people are serious students of government. "Too many laws are worse than not enough," he told the guests. W. H. Schneider, president of the club, was toastmaster at the dinner.

Russian Government Engages American Engineers

AGREEMENT providing for technical services has been consummated between the Soviet Government and Freyn Engineering Co. of Chicago, Ill. By the terms of this agreement, the Freyn Engineering Co. will send to Leningrad a group of engineers and specialists who will coöperate with Gipromez, the State Institute for Projecting New Metal Works, located at Leningrad, U. S. S. R., in the planning, designing and construction of new iron and steel plants, as well as in the reconstruction and modernization of existing metallurgical plants.

The group of Freyn engineers will sail from New York about the middle of April, and will begin work in Leningrad on May 1. They will be in charge of L. E. L. Thomas, vice president of Freyn Engineering Co., who is now on his way back from Leningrad where he has completed detail arrangements for the extended sojourn of the group of engineers.

The program of the Soviet Government for the ensuing five-year period calls for the planning and construction of ten new iron and steel works, as well as the extensive remodeling of old plants. The total estimated

value of the investments to be made in the iron and steel industry alone, amounts to over one billion dollars.

The Freyn company will coöperate in this huge task by giving to the Soviet Union the benefit of its American knowledge and experience. The group, which is to form the nucleus around which it is expected a larger organization will be built up, this has been selected and will comprise specialists for coke oven plants, blast furnaces, open hearth and bessemer plants, rolling mills and power and electric stations.

News Notes

NATIONAL EXPOSITION of Power and Mechanical Engineering has announced that it will hold annual exhibits in 1929 and 1930 because of contracts already made but that, after 1930, the exhibits will be biennial, i. e., in 1930, 1932, 1934 and 1936. In the intermediate years, exhibits dissimilar in character from the power show will be held.

UNIVERSITY OF IOWA colleges of engineering and commerce are sponsoring a power and industrial conference at Iowa City, April 2-4. Power facilities of Iowa, power as a factor in production, power utilization in Iowa industries, extension of manufacturing in the state and review of progress in the last year, are the chief topics of discussion. Among the speakers will be W. G. Jamison, United States Department of Commerce; William J. Barrett, Metropolitan Life Insurance Co., New York; A. D. Altree, Edison Lamp Works, Chicago; and G. C. Heisterman, Public Service Co., Chicago.

FRED W. HOOVER has been appointed head of the newly organized industrial development department of the Allied Power and Light Corp., coöperating with the Illinois Power Corp. and local civic groups in securing new industrial projects for their communities. Mr. Hoover was formerly with the Commonwealth Power Corp. A. D. Mackie, Springfield, Ill., vice president and general manager of the Illinois Power Corp., launched the new bureau, which will assist in making industrial surveys and interesting industries, with particular emphasis upon the electric power facilities obtainable in the various communities.

J. A. PEARSON, vice president in charge of purchasing for the United Gas Improvement Company, Broad & Arch Sts., Philadelphia, Pa., has tendered his resignation effective April 1. Mr. Pearson has been in the U. G. I. employ for 40 yrs.

FRED L. A. SCHMIDT, industrial power plant specialist in the Cleveland district office of the General Electric Co. for the past 12 yr., resigned, March 1, to join the power plant engineering staff of the H. K. Ferguson Co., Hanna Building, Cleveland, Ohio.

RILEY STOKER CORP., Worcester, Mass., announces that L. F. Lang has been appointed assistant to M. L. Cornelious at its Cincinnati office. K. E. Pote has been appointed district manager of the Pittsburgh office to succeed E. H. Schmitz, while E. H. Schmitz has been appointed district manager of the Boston office.

READING IRON CO., Reading, Pa., has appointed E. W. McHenry as district sales representative at Houston, Texas.

WAGNER ELECTRIC CORP., St. Louis, Mo., announces the addition of K. G. Baker to its Cincinnati sales force. Mr. Baker is a graduate of Purdue University and has previously been connected with Century Electric Co. and Fulton Iron Works, both of St. Louis.

ACCORDING to a recent announcement, the Baldwin Locomotive Works, Philadelphia, Pa., has purchased a substantial interest in the business of George D. Whitcomb Co., Rochelle, Ill.

GEORGE F. KLEIN, formerly chief engineer of A. E. Staley Manufacturing Co., Decatur, Ill., has left that organization to become director of the Kansas City Coal Service Institute with headquarters at 1004 Baltimore Ave., Kansas City, Mo. The Kansas City Coal Service Institute is an organization of retail and wholesale coal dealers of Kansas City, established to further by educational means the proper use of coal and to assist in regulating smoke, lowering cost of fuel to all users and to cooperate with those desiring to obtain the lowest cost for heating homes, apartments, office buildings and industrial plants. As director of this service, Mr. Klein will have charge of the advertising, sales and engineering campaigns involved in the program. He had been with the Staley Co. for three years, coming to Decatur from the Union Electric Light & Power Co. of St. Louis.

AT THE ANNUAL meeting of the J. E. Lonergan Co., officers were elected as follows: President and Treasurer, James P. Cavanaugh; Vice President, A. St. C. Tomes; Secretary and Assistant Treasurer, A. A. Syckelmoore.

R. J. S. PIGGOTT, who for 3 yr. was mechanical engineer with Stevens & Wood, Inc., and later consulting engineer with Public Service Corp. of New Jersey Production Co. and Smoot Engineering Corp., has returned to the Stevens & Wood organization as consulting mechanical engineer. For several years, Mr. Piggott was chairman of the A. S. M. E. main research committee and has had wide experience with industrial and power plants. In his new assignment, he will devote his time mainly to solving the problems of industrial companies both in matters of power and production.

WELLMAN-SEAVER-MORGAN CO., Cleveland, Ohio, has completed shipment of one of its 60-ft. heavy duty, 4-clamp, revolving car dumpers to the Detroit Edison Co.'s new Delray plant at Detroit, where it is now being erected. This dumper is designed to handle open top railway cars of 120 t. capacity of coal and a tare weight of 40 t., at the rate of 20 cars an hour. A similar dumper of 52-ft. size and smaller capacity is now under construction in the Wellman shops for the Duke Power Co.'s new River Bend power plant at Mount Holly, N. C.

H. HOBART PORTER has been elected chairman of Engineering Foundation, 29 West 39th St., New York City, to succeed L. B. Stillwell, who has served since 1925. Mr. Porter is president of the American Water Works and Electric Co. and of the Brooklyn City Railroad Co. He is chairman of the board of the West Penn Electric Co. and vice president of Queensboro Gas and Electric Co. In addition, he is a member of various boards of directors of banks, public utilities and transportation companies. He is a member of the Division

of Engineering and the executive committee of the National Research Council and of various engineering societies. Officers re-elected by the Foundation include G. A. Orrok, vice chairman, Arthur D. Little, vice chairman, Alfred D. Flinn, director.

Bailey Meter Co., 1050 Ivanhoe Road, Cleveland, Ohio, announces that it has transferred its office in Cincinnati, Ohio, to Room 412 Union Central Bldg., and that E. R. Dearborn will continue as branch manager at the new address.

Northern Equipment Co., Erie, Pa., has appointed R. L. Sittinger, Room 303, Chamber of Commerce Bldg., 80 Federal St., Boston, Mass., as its representative for New England. Harry H. Leathers, the former representative, is relinquishing the account to Mr. Sittinger in order to devote his entire time to his other business interests. Northern Equipment Co. has also appointed Messrs. Peacock Bros., Ltd., Montreal, as its representative for the Toronto territory. This company has a branch office at 610 Federal Bldg., Toronto.

Roller-Smith Co., 233 Broadway, New York, N. Y., announces that Jackson Brown, Jr., 701 Kittridge Bldg., Denver, Colorado, is its representative in Colorado, Utah, Wyoming and Northern New Mexico. The Manila Machinery & Supply Co., Inc., Manila, Philippine Islands, is representing the Roller-Smith Co. in the Philippine Islands.

Hardinge Co., York, Pa., announces that its New York office was moved on March 23 from 120 Broadway to the Chanin Bldg., 122 East 42nd St., New York City.

According to a recent announcement in the Staley Journal, published by A. E. Staley Manufacturing Co., Decatur, Ill., John C. Kuhns took over full control of its power house and boiler room on January 15, succeeding G. F. Klein. Mr. Kuhns will not only have supervision of the power house and boiler room but will also act in an advistory capacity in the control of steam and electrical distribution. He is a graduate of the University of Illinois and has been with the Staley Co. for a number of years in various capacities.

Cutler-Hammer, Inc., Milwaukee, Wis., announces that, on March 1, P. S. Jones became manager of its New York district office, succeeding C. W. Yerger. Mr. Jones was formerly manager of the Pittsburgh office of Cutler-Hammer, Inc., and he will be succeeded by T. S. Towle, formerly a sales engineer of the Pittsburgh office. G. E. Hunt, who has been in the Cutler-Hammer Philadelphia office for the past 10 yrs., has been placed in charge of distributors' sales for the company.

Link-Belt Co., Chicago, Ill., announces that James S. Watson has been elected vice president with headquarters at the company's Dodge Works, Indianapolis, Ind. Mr. Watson has been with the company continuously for 34 years. For the past nine years, he has been at the company's Dodge Works in Indianapolis, of which he is general manager in full charge of production.

John E. Zimmermann, Chairman of the Executive Committee of The United Gas Improvement Co. of Philadelphia, Pa., was recently elected by the board of directors to the office of president which duties he assumes in addition to those he is already carrying as chairman of the executive committee.

Mr. Zimmermann has been prominent in Philadelphia engineering circles since 1899 when he entered the employ of the American Pulley Co. as superintendent of manufacture and later as secretary. After eight years' association with this company, he, together with Charles Day, formed the engineering and construction firm of Day & Zimmermann of which he was president for a number of years. This company is now a subsidiary of the U. G. I. Co. and at the time of the consolidation, Mr. Zimmermann was elected a member of the Executive Committee. Mr. Zimmermann, in addition to being the Chairman of the Executive Committee of several Philadelphia utility companies, is also a director in a number of other public service utilities and banking institutions.

H. P. Ackerman, who, for several years, has been the Eastern District Sales Manager for the Homestead Valve Mfg. Co., has established a manufacturers agency known as the Steam Specialty Sales Co. with headquarters at 908 Trade St., Charlotte, N. C. His organization will cover the territory including North and South Carolina and a portion of the state of Georgia and will handle a complete line of the Homestead Valve Co.'s products as well as a number of other steam specialties.

Union Carbide Co. and associated companies have removed their technical publicity department, formerly at 30 E. 42nd St., to 205 E. 42nd St., New York City.

Blaw-Knox Co. of Pittsburgh, Pa., announces the merger of A. W. French & Co. of Chicago, a manufacturer of road making machinery, with Blaw-Knox Co. and subsidiary companies. The personnel and policies of A. W. French & Co. will continue as heretofore and its plant and sales organization will function as a separate division of Blaw-Knox Co.

Reading Iron Co., Reading, Pa., announces the establishment of a new district sales office in New Orleans which will be under the direction of George E. Tyson, located in the Hibernia Bank Bldg. Mr. Tyson was formerly of the Reading district.

Bailey Meter Co. of Cleveland, Ohio, announces the formation of a subsidiary company, Bailey Meters (Aust.) Limited, with headquarters at Kembla Buildings, Margaret St., Sydney, N. S. W., Australia. C. W. Payn is managing director.

Chicago Pump Co., Chicago, Ill., has recently added two new representatives to its staff as follows: Bernhard E. Hovind, 326 Jay St., La Crosse, Wis.; S. T. Weaver Co., 1002 N. Clinch St., Knoxville, Tenn.

Dayton-Dowd Co., Quincy, Ill., has recently appointed D. C. Elphinstone, Inc., 120 S. Calvert St., Baltimore, Md., as district representative for the Maryland district, W. C. Reamy, Jr. being in charge of pump sales.

McClave-Brooks Co., Scranton, Pa., has moved its Atlanta office to Greenville, S. C., where it will be located in room 214, Emaxcee Bldg., in charge of John W. Littlefield, district manager.

World's largest condenser, for the world's largest single-unit turbine-generator, has arrived at the East River Station of the New York Edison Co. and is now being assembled there. This unit was manufactured by the Ingersoll-Rand Co. at its Phillipsburg, N. J., factory and, as it was too large to ship completely

assembled, it was sent in parts. These parts occupied some 20 full carloads. This condenser is capable of condensing nearly 700 t. of steam per hour, having some 90,000 sq. ft. of cooling surface. Nearly 80 mi. of 7/8-in. tubes will be used and two 54-in. centrifugal pumps will provide the cold water for condensing. These giant pumps will pump about 160,000 gallons of water per minute from the East River.

VULCAN SOOT CLEANER Co., DuBois, Pa., announces the opening of an office in New York City which will be in charge of Mr. Linaker, vice-president. The location will be at 120 Liberty St.

BINKS MANUFACTURING Co. has been organized as the successor to the Binks Spray Equipment Co. to take over the manufacture of cooling systems and painting equipment. Officers of the new organization will be: Neil C. Hurley, president; M. S. Sullivan, vice president; J. F. Roche, secretary and treasurer. Directors: George A. Hughes, N. L. Howard, Neil C. Hurley, Robert Chambers, J. F. Roche, Wm. Hoch and Paul Morrison. The company's offices will be located at 3124 Carroll Ave., Chicago, Ill.

BISMARK KING, who has been associated with the Central Illinois Public Service Co., Springfield, Ill., for the last 18 yr., has resigned that position, effective April 1, when he becomes vice president and general manager of the Central Atlantic States Service Co. of Newark, N. J.

H. H. WOOD, FORMERLY chief engineer of the Laclede Steel Co. of St. Louis, has joined the Industrial Department of The Timken Roller Bearing Co., Canton, Ohio. Mr. Wood will specialize in the application of Timken bearings to steel mill equipment of various sorts. For the present, his headquarters will be in Canton.

Books and Catalogs

FUNDAMENTALS OF QUANTITATIVE ANALYSIS, by Walter C. Blasdale; published by D. Van Nostrand Co., 8 Warren St., New York, N. Y.; third edition, 397 pages; price, $3.75.

Quantitative analysis has for its object the determination of the quantity of some element or compound present in a particular substance and as such is of interest to the power plant engineer from the standpoint of fuel and water laboratory work. This book assumes a knowledge of some chemistry, so its chief value to the practical man lies in the practical discussion of methods and practices such as included in the introductory statements and definitions, correct methods of weighing, corrections for buoyancy and general directions for quantitative procedure such as sampling, mixing, powdering, drying, evaporating, sample calculations and general discussion of chemical reactions.

ILLINOIS STATE GEOLOGICAL SURVEY announces that Bulletin 56, "Illinois Coal: A Nontechnical Account of Its Occurrence, Production and Preparation," by A. Bement, is now available for distribution. In this publication, coal, the most important mineral resource of Illinois, is briefly discussed in a manner especially adapted for the general public and the bulletin should be of particular interest to many students and teachers in secondary schools and colleges. It consists of 110 pages and includes 50 illustrations. The bulletin provides an excellent short summary of the physical conditions controlling the character and the production of coal within the Illinois coal field. The price of the bulletin is 25 cents. Remittance may be made in stamps if more convenient. Address all requests to: M. M. Leighton, Chief State Geological Survey, Urbana, Ill.

IN A HANDSOME book having the title, Wherever Wheels and Shafts Turn, the Timken Roller Bearing Co. of Canton, Ohio, describes the construction of its bearings and shows the advantages obtained by their application to all kinds of industrial machinery. Lowered friction, less lubrication, greater precision, smaller wear, readier adjustment are listed among the benefits. Application is shown to automobiles, aircraft, railway cars, shop trucks, steel mills, rollers and tractors, conveying and transmission systems, pumps and motors, compressors and engines, fans and blowers, machinery for woodworking, paper mills, flour mills, printing, textile mills, lumber mills, clay working, laundries, household and farm machinery. Construction, capacity and sizes of bearings are given in a detailed table with suggestions for housing design.

CABLE SHEATH CORROSION, an article in pamphlet form by John Francis Murray, is issued by the Murray Conduit Systems, 88 Lexington Ave., New York.

IN A RECENT 4-page folder, Warren Webster & Co., Camden, N. J., presents discussion of the characteristics of the new Webster moderator system of steam heating, described in detail in the Feb. 1, 1929 issue of Power Plant Engineering.

SKIP HOISTS, their design, application and details of various parts, are discussed in a recent 24-page bulletin by Stephens-Adamson Mfg. Co., Aurora, Ill. Data for selecting units are presented, with tables of data on hoist machines and other engineering information.

FORCED DRAFT STOWE STOKER is described and illustrated in a 4-page folder issued by the Johnston & Jennings Co., 877 Addison Road, Cleveland, Ohio.

HIGH-PRESSURE type rotary gas pumps for pressures of 10 lb. or less are illustrated and described in a new 16-page bulletin No. 33-B1 by the P. H. & F. M. Roots Co., Connersville, Ind. The bulletin gives tabulated data on pressures, capacities and horsepowers, brief review of various types of pumping units and a 2-page construction drawing showing the typical unit in detail.

AN INTERESTING new 12-page booklet entitled, Control of Boiler Water Concentrations, has been issued by The Elgin Softener Corp., formerly the Reiter Co., of Elgin, Ill. It is illustrated with charts and photographs.

HAYS CORP., Michigan City, Ind., is sending out an illustrated 16-page bulletin, describing Hays flue gas analyzers and portable combustion test sets. Details of the instrument and its operation are fully covered and there are many illustrations of methods of employing it. The company is also sending out catalog RA29 describing Hays CO_2 and draft recorders in detail.

WAGNER ELECTRIC CORPORATION of St. Louis, Mo., has just issued the fourth edition of its bulletin on Manual of Electrical Testing, a 20-page bulletin on testing single-phase and polyphase motors, and testing transformers for core loss, copper loss, polarity, insulation, temperature rise and efficiency. Any person desiring a copy of this manual should ask for Bulletin 138.

Power Plant Construction News

Ala., Gadsden—The Gulf States Steel Co., Birmingham, Ala., plans installation of power equipment in connection with an expansion and improvement program at its mill at Gadsden, entire project to cost more than $3,500,000. W. H. Coverdale is president.

Ariz., Globe—The City Council has authorized plans for the installation of a water-softening plant for the municipal waterworks, reported to cost about $25,000. The Burns & McDonnell Engineering Co., Interstate Building, Kansas City, Mo., is engineer.

Ariz., Phoenix—The Terminal Cold Storage Co. is having plans completed for construction of six-story cold storage and refrigerating plant at Madison and Twelfth Streets, to cost $450,000, with equipment. H. D. Frankfort, Securities Building, is architect; R. J. Morris, 763 East McKinley Street, is refrigerating engineer.

Calif., Los Angeles—The Pacific Electric Railway Co., is having plans drawn for an addition to its Toluca power substation on the Glendale Boulevard, reported to cost more than $75,000, with equipment. Engineering department of company is in charge.

Conn., Bristol—The Wallace Barnes Co., Main Street, will install power equipment in two new multi-story additions to wire mill to cost more than $250,000, for which plans have been filed.

Conn., New Haven—The Seamless Rubber Co., Hallock Street, has filed plans for two-story addition to power plant, 32 x 54 ft., reported to cost about $45,000, with equipment. Dwight E. Smith, New Haven, is architect.

Ga., Atlanta—The B. F. Goodrich Co., Akron, Ohio, will install power equipment in proposed new rubber mill on site just acquired at Atlanta, entire project to cost about $1,500,000. A boiler plant is projected.

Ill., Chicago—The Evans Fibre Box Co., 3301 West Forty-seventh Place, plans installation of power equipment in proposed plant addition to cost $100,000. A. Epstein, 2001 West Pershing Road, is architect and engineer.

Ill., East St. Louis—The Mobile & Ohio Railroad Co., Fullerton Building, St. Louis, Mo., will install power equipment in proposed shops and engine house at East St. Louis, to cost about $200,000. C. A. Hayes is company architect.

Ill., Rockford—The Rockford Organ Co. plans installation of power equipment in proposed pipe organ manufacturing plant at Ninth Street and Twenty-fourth Avenue, to cost about $200,000. Peterson & Johnson, Swedish American Bank Building, Rockford, are architects.

Ind., Kokomo—The Continental Steel Corporation, Kokomo, plans installation of power equipment in proposed new rolling mill unit to cost more than $250,000. Henry Roemer is president.

Iowa, Ottumwa—The City Council is said to have plans maturing for a municipal hydroelectric power plant, including power dam, power house and equipment and head race, reported to cost $750,000. John Brady, City Hall, is city engineer; Brown & Cook, 106 North Market Street, are consulting engineers.

La., Baton Rouge—The Standard Oil Co. of Louisiana, New Orleans, plans installation of power equipment in proposed new refining plant at Baton Rouge, entire project to cost close to $500,000.

Mass., Chelsea—The Intercontinental Pipe & Mining Co., recently organized, care of the Chamber of Commerce, Chelsea, will install power equipment in proposed local plant for manufacture of cast iron pipe, for which site has been secured in cooperation with Chamber of Commerce, complete project to cost more than $2,000,000.

Mass., Millbury—The New England Power Co., Worcester, Mass., is said to be planning construction of new steam-operated electric power plant in vicinity of Millbury with initial capacity in excess of 50,000 kw., reported to cost more than $400,000.

Mich., Jackson—The Sparks-Withington Co. will install power equipment in proposed addition to automobile accessory plant, for which bids will soon be asked on general contract. Estimated to cost close to $150,000.

Minn., St. Peter—The Board of Trustees, Gustavus Adolphus College, Dr. O. J. Johnson, president, is having plans prepared for extensions and improvements in power plant, to include installation of boilers, stokers, pumping equipment and auxiliaries. William M. Ingemann, Endicott Building, St. Paul, Minn., is architect.

Miss., Holly Bluff—The Lake George Hardwood Lumber Co. plans installation of power equipment in connection with proposed rebuilding of portion of mill destroyed by fire, March 6, with total loss reported at $100,000.

Mo., Poplar Bluff—The Missouri Pacific Railroad Co., St. Louis, Mo., plans installation of power equipment in new addition to repair shops and engine house at Poplar Bluff, to cost more than $150,000.

N. C., Greensboro—The Mock, Judson, Voehringer Co., Howard and Hiatt Streets, will install power equipment in proposed addition to hosiery mill to cost more than $100,000.

N. J., Jersey City—The Brunswick Laundry Co., 222 Tonnele Avenue, has completed plans for construction of new steam power house on Liberty Avenue, for mechanical laundry service, reported to cost more than $100,000. Peter Simeone & Co., 100 Sip Avenue, Jersey City, is architect and engineer.

N. Y., Conklinville—The New York Power & Light Corporation, Albany, N. Y., has approved plans for a hydroelectric power project at the Conklinville dam, Conklinville, to cost more than $500,000, with transmission system.

Ohio, Cleveland—The Widlar Co., Bolivar Road, will install power equipment in proposed addition to spice mill to cost more than $200,000, for which plans have been drawn by Harlen E. Shimmin, Bulkley Building, architect.

Ohio, Toledo—The Toledo Seed & Oil Co., Toledo, will install power equipment in proposed addition to linseed oil mill to cost more than $100,000.

Pa., Bloomsburg—The Magee Carpet Co. will install power equipment in new four-story mill addition to cost more than $200,000. The Ballinger Co., Twelfth and Chestnut Streets, Philadelphia, Pa., is architect and engineer.

Pa., Williamsport—The Lycoming Mfg. Co. will install power equipment in new one-story plant unit, for which superstructure has begun, for manufacture of aircraft engines, entire project to cost more than $400,000.

S. C., Spartanburg—The A. M. Jamison Tobacco & Cigar Co., Spartanburg, plans installation of power equipment in connection with proposed rebuilding of portion of plant recently destroyed by fire with loss of about $100,000.

Tenn., Chattanooga—The Davenport Hosiery Mills, Inc. will install power equipment in connection with a general expansion and improvement program for increased output, entire project to cost close to $200,000.

Texas, Fentress—The San Antonio Power & Light Co., San Antonio, Texas, plans construction of power substation and extensions in transmission lines at Fentress and vicinity, following recent acquisition of the Fentress Gin & Power Co.

Va., Harrisonburg—The Consumers Utilities Co., Winchester, Va., is projecting plans for a new artificial gas plant at Harrisonburg, to cost about $200,000, with equipment. A franchise has been asked.

W. Va., Newell—The Homer Laughlin China Co., Newell, plans installation of power equipment in proposed new plant unit, entire project to cost more than $1,000,000. It is proposed to begin work during summer.

Wash., Camas—The Crown Willamette Paper Co., San Francisco, Calif., will install power equipment in proposed additions to mill at Camas, entire project to cost more than $2,000,000.

Wis., Milwaukee—The Chicago, Milwaukee, St. Paul & Pacific Railroad Co., Union Station, Chicago, Ill., will install power equipment in proposed addition to car repair shops, 200 x 1000 ft., at West Milwaukee, entire project reported to cost more than $400,000. C. N. Bainbridge is engineer.

Wyo., Casper—The Midwest Refining Co., First National Bank Building, Denver, Colo., will install power equipment in proposed refinery expansion and improvements at Casper, entire project to cost more than $500,000.